Final Report

For

Louisiana's Oyster Shell Recovery Pilot Project

NOAA Award
No. NA96FK0188

Final Report Produced By:

Louisiana Department of Wildlife and Fisheries

Socioeconomics Research and Development Section
and
Marine Fisheries Division

March 29, 2004

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Project Objective

The objective of this project was to develop and implement methods to restore and enhance suitable shellfish habitat on Louisiana's public oyster seed grounds lost or damaged as a result of Hurricane Andrew by developing a framework for recycling oyster shells for use in oyster reef restoration and comparing alternative cultch materials for restoring oyster reefs.

Project Need

The capacity for increased oyster production on Louisiana's public oyster seed grounds is largely dependent upon the amount of quality habitat available for larval oyster attachment and oyster spat growth. Hard, clean substrate is critical to developing a viable oyster reef and the Louisiana Department of Wildlife and Fisheries (LDWF) has been depositing cultch material (mainly native shell materials) on public oyster grounds to build and enhance reefs since 1919. Unfortunately, much of the oyster shell produced from in-state shucking operations is utilized for projects such as road base construction and poultry feed additive. In addition, a portion of the shell supply is lost when oysters are shipped out of state and a small amount is also lost to landfills. Therefore, Louisiana experiences a shell deficit as a far greater amount of shell is removed from public oyster grounds than is returned for habitat development and enhancement.

The feasibility of alternative cultch materials also needs to be established in order to provide options to resource managers when planning reef building projects. Historically, relic clam shells have been used to develop oyster habitat, but this source of cultch material is no longer available. The usefulness of alternative materials such as limestone and crushed concrete for reef building is not well known and should be further researched.

This project examined the feasibility of recapturing the harvested oyster shell for use in future reef building projects, as well as the suitability of limestone and crushed concrete as alternative cultch materials. It also examined the perceived value of oyster reefs to recreational anglers. If oyster shell can be cost-effectively recaptured, it can be used in future reef-building or reef enhancement projects. If it is not cost-effective to recapture shell, and alternative cultch materials are effective in recruiting larval oysters, alternative cultch materials should be considered for reef building projects.

Project Summary

Louisiana's Oyster Shell Recovery Pilot Project focused on addressing three major issues: 1) feasibility of recapturing shell for use in reef-building projects on public seed grounds, 2) determining the perceived value of oyster reefs to recreational fishermen, and 3) performance of alternative cultch materials (limestone and crushed concrete) in production of seed oysters. The LDWF Socioeconomics Section worked diligently to address issues 1 and 3, while issue 2 was researched by a private consulting company, Cirino Consulting Services. Each issue is addressed in this final report as a separate section.

Feasibility of Recapturing Shell for Use in Reef-Building Projects on Public Seed Grounds

Louisiana's oyster harvesters annually extract from the state's waters the largest commercial oyster harvest in the United States with an annual average of 11.8 million pounds of oyster meat for the period 1990 to 2002. In order to support this level of output, the Louisiana Department of Wildlife and Fisheries periodically deposits suitable cultch materials (native shells, limestone, or crushed concrete) on public oyster grounds [Section 2]. One cultch material with an established record of productivity is oyster shell, the by-product of oyster processing and consumption.

Only a portion of Louisiana's commercial oyster harvest is processed within the state. The majority of oysters are shipped directly to consumers or restaurants or to processors in other states. This reduces the amount of readily available stockpiles of oyster shells in Louisiana that may be obtained, collected, and deposited as cultch. Furthermore, the processors who are located within Louisiana are geographically dispersed throughout the southern region of the state, making efforts to collect shells from all the state's processors on a regular basis costly and complicated.

One area of Louisiana, Terrebonne Parish, does have a sufficiently large volume of oyster processing to consider establishing a test program for oyster shell collection and deposition. The processors have indicated a willingness to provide up to 7,000 cubic yards of shells per year to the oyster shell collection effort. Local government offered to provide land for stockpiling the collected shell.

The most cost effective means of collecting these shells is to establish a Department-run program to transport the shells by truck from processors to a water-accessible stockpiling site and to use existing resources (barges, cranes, and tug boats) to deposit them on public reefs. Somewhat more expensive method is to hire a subcontractor to operate the ground transportation and to use Department resources to perform the deposition on public grounds.

Although perhaps attractive for social reasons, oyster shell collection is not the least expensive means of cultch material acquisition and deposition. It is less costly to hire a private contractor to obtain oyster shell, crushed concrete, or crushed limestone independently and then to deposit the selected material on public grounds. Because the private contractor may not be able to obtain a sufficiently large quantity of oyster shells, it may likely use another cultch material.

Determining the Perceived Value of Oyster Reefs to Recreational Fishermen

This effort employed the contingent valuation method to estimate the value of Louisiana's oyster reefs as recreational fishing grounds [Section 3], using a sample drawn from resident saltwater anglers who participated in the National Marine Fisheries Service's Marine Recreational Fishing Statistical Survey. Personnel in the Department's Socioeconomic Research and Development Section conducted a telephone survey featuring a dichotomous-choice willingness to pay question. The average willingness to pay among resident saltwater recreational fishermen to maintain access to recreational fishing over Louisiana's oyster reefs was $13.21.

Performance of Alternative Cultch Materials in Production of Seed Oysters

Two alternative cultch materials, crushed concrete and limestone, were compared with oyster shell to determine the performance of each material in producing seed-sized (< 3") oysters. Nine random test plots were constructed (three of each material) in Lake Borgne, Louisiana in October 2000 and sampling began approximately eight months later [Section 4]. Three replicate 0.33 square-meter samples were collected by divers utilizing SCUBA equipment at each test plot. Sample results showed that significantly more live oysters were present on both limestone and crushed concrete test plots than on plots constructed with oyster shell. Average oyster size also showed differences among cultch materials as oyster size was significantly larger on crushed concrete and limestone test plots than on oyster shell plots. These results indicated that at the Lake Borgne cultch planting location, limestone and crushed concrete appear to be viable alternatives to oyster shell for oyster reef building and enhancement projects.

Section 2.

Alternative Oyster Shell Recovery and Planting Approaches in Louisiana

Final Report Submitted to the National Marine Fisheries Service under
Grant Number NA96FK0188

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Chapter 2-1. Introduction

Louisiana has some of the most productive oyster reefs in the United States and is home to an experienced population of oyster harvesters who apply their knowledge and expertise to produce the largest commercial oyster harvest in the country. The Louisiana Department of Wildlife and Fisheries (Department), among other government agencies, works with these commercial harvesters to assure the continued productivity of the state's shellfish resources. In addition to licensing harvesters, administering leases, enforcing laws, and monitoring environmental conditions, the Department must maintain the public reefs from which many harvesters obtain adult (market) oysters for immediate sale or immature (seed) oysters for transfer to private leases where they may grow to marketable size.

One important practice in reef maintenance or restoration is planting cultch, hard material deposited on water bottoms to provide solid substrate on which oyster larvae may settle and develop into adult oysters. Like the oyster harvesters who deposit cultch on their private leases to improve the yields of their individual leaseholds, the Department periodically places cultch on public reefs, a function it has performed for over 80 years.

Recent developments have raised concerns about the state's ability to deposit cultch, namely the availability of cultch materials. Beginning in the early 1990's, concerns about the impact of shell dredging in Lake Pontchartrain on water quality restricted access to *Rangia* clam shells, once a common form of cultch. In 1999, the Louisiana Legislature codified this ban and forbade shell dredging in all state-owned water bottoms (Louisiana R.S. 36:609(C) (1)). The ban on shell dredging has reduced the availability of natural hard substrate, forcing the Department to search for alternative cultch materials.

At the same time, harvests from public reefs have increased, increasing the need for pubic oyster reef enhancement. The Department therefore wishes to identify alternative sources of cultch in order to maintain sustainable harvests in the face of increasing harvesting effort.

The purpose of this report is to examine alternative measures for obtaining and depositing suitable cultch materials for use on Louisiana public oyster grounds to maintain and produce oysters for human consumption. Chapter 2-2 will begin with an examination of commercial oyster harvesting at the national level and within the state of Louisiana. Chapter 2-3 will examine oyster processing among the Gulf of Mexico states with a focus on Louisiana to detect trends and to identify potential sources of oyster shells for use as cultch. Chapter 2-4 will discuss different states' oyster reef enhancement programs. Chapter 2-5 will examine the feasibility of three potential programs for collecting cultch, in particular oyster shell, in Louisiana. Chapter 2-6 will discuss the productive potential of alternative non-traditional types of cultch materials. Chapter 2-7 will provide the findings and conclusions of this study.

Chapter 2-2. Oyster Consumption, Imports, and Harvests

Consumers in the United States consumed 4.48 billion pounds of seafood (15.6 pounds per capita) in 2002, up from 4.20 billion pounds (14.8 pounds per capita) in 2001. Shrimp and canned tuna are the most commonly consumed seafood items, a distinction they have held since 1990 (National Marine Fisheries Service, 2003).

Annual per capita consumption of oysters in the U.S. is roughly one-fifth of a pound (Johnson, 2000). Oysters typically rank among the "top 20" seafood products consumed in the U.S., but have appeared in the "top 10" once (1998) since 1990. Among bivalves, oysters rank third, below clams and scallops in terms of total consumption.

Commercial Oyster Harvests

The United States in 2002 (Figure 2-1) reported a commercial oyster harvest of 34,714,004 pounds of oyster meat with a dockside value of $88,845,592 ($80,286,998 in inflation adjusted 1996 dollars). The total commercial oyster harvest has usually ranged between 35 and 37 million pounds of oyster meat every year since 1992. During the same period, the dockside value of the harvest has declined from $116.8 million in 1992 to $79.9 million in 2001 (in 1996 dollars). Oysters are ranked eleventh (by dockside value) among commercial seafood products in the U.S. (Table 2-1).

Six of the National Marine Fisheries Services' commercial seafood regions reported commercial oyster harvests in 2001 (Figure 2-2). The top U.S. commercial oyster production areas are situated on the Gulf of Mexico and the Pacific Coast. The five states on the Gulf of Mexico produced nearly two-thirds of the U.S. oyster harvest by volume (Figure 2-3) and over one-half by value (Figure 2-4). The Pacific Coast accounted for over one-quarter of U.S. oyster production by volume and value.

Figure 2-1. Quantity and Value of U.S. Commercial Oyster Harvest: 1980 - 2002

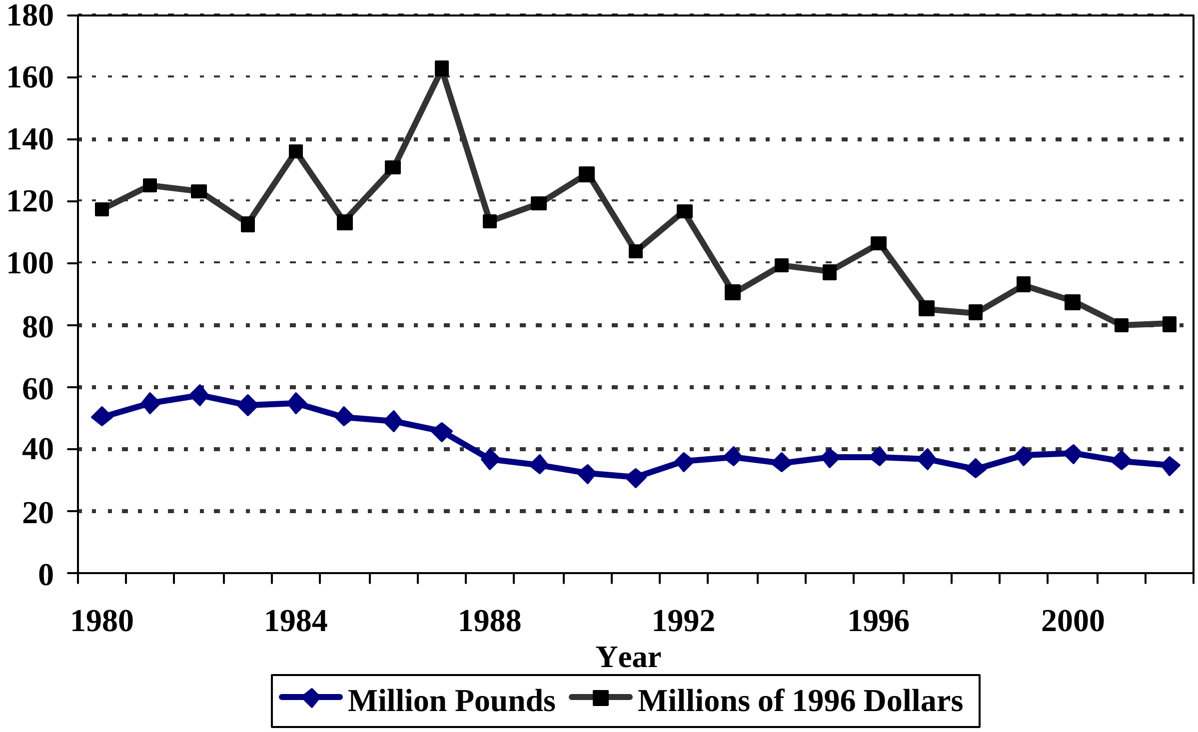


Table 2-1. Top Fifteen Commercial Seafood Product Classes, U.S. by Dockside Value, 2002

Rank	Seafood Class	Pounds (Millions)	Dockside Value (Millions of 1996 Dollars)
1	Shrimp (All)	365.7	528.7
2	Crabs (All)	312.5	361.2
3	Lobsters (All)	86.2	283.1
4	Pollock (All)	3,349.7	189.7
5	Scallops (All)	53.1	184.1
6	Clams (All)	130.1	151.8
7	Salmon (All)	567.2	140.2
8	Halibut (All)	88.4	127.6
9	Cod (All)	541.7	114.7
10	Atlantic Menhaden	1,749.2	95.0
11	**Oysters (All)**	**34.71**	**80.3**
12	Tuna (All)	49.7	76.8
13	Sablefish	40.9	70.7
14	Founder (All)	87.9	58.2
15	Squid (All)	205.6	39.4
Source: National Marine Fisheries Service, 2003			

Figure 2-2. National Marine Fisheries Service's Seafood Harvest Regions

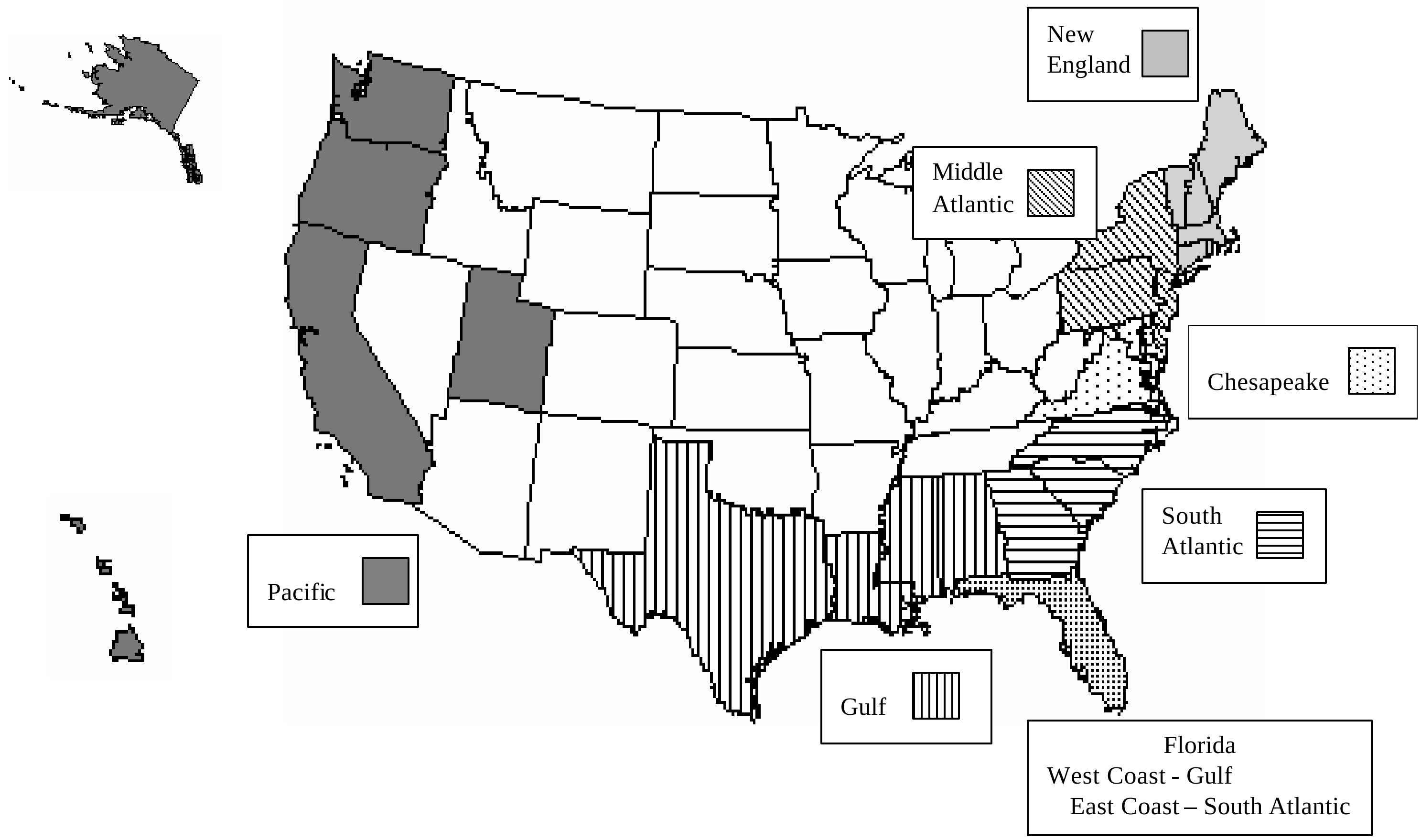


Figure 2-3. Volume of U.S. Commercial Oyster Harvests, by Region: 2002 (Millions of Pounds of Meat, Percentage of U.S. Harvest)

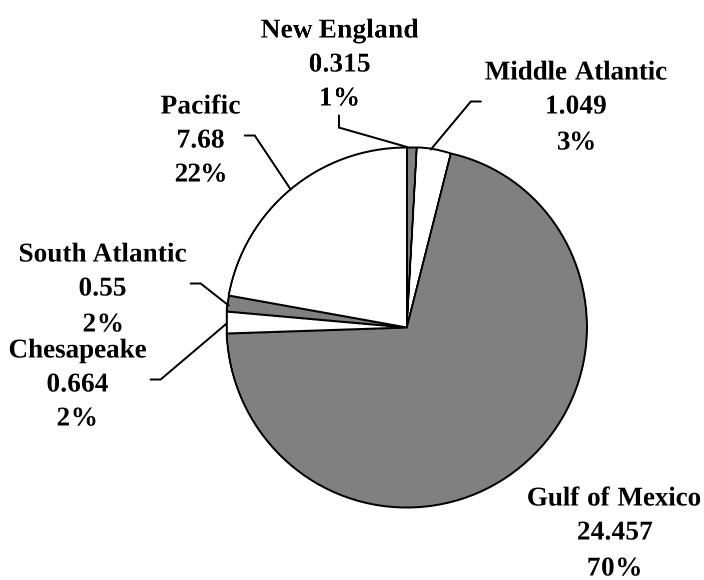
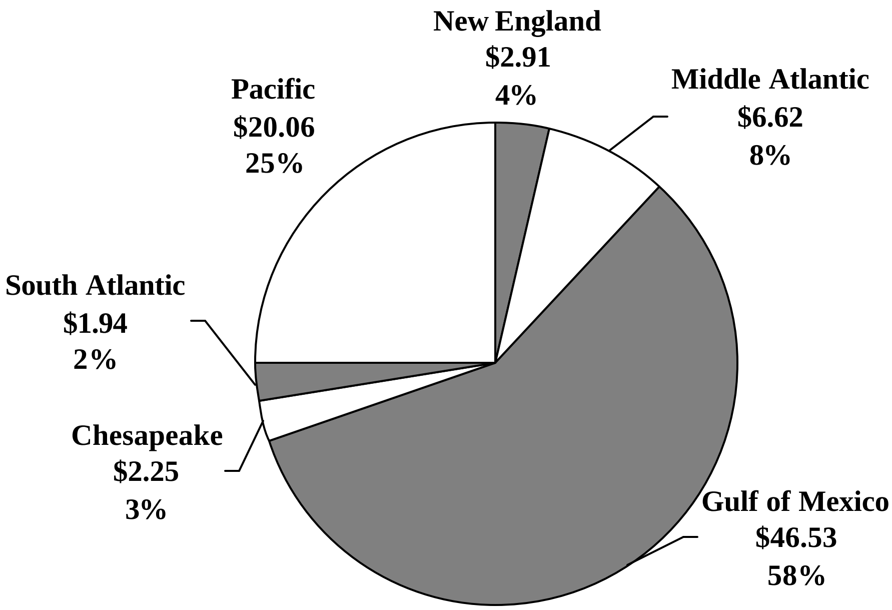


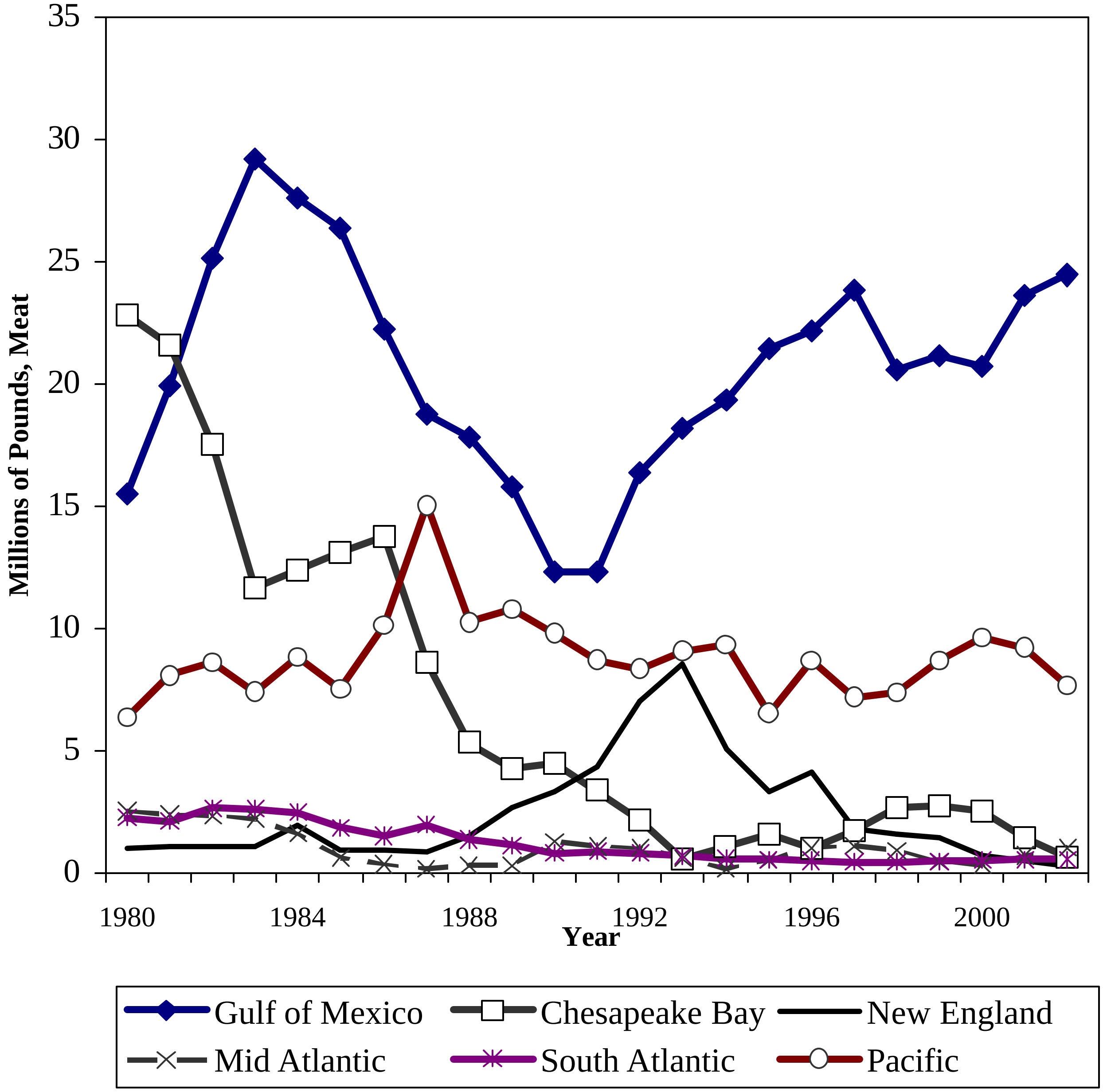
Figure 2-4. Value of U.S. Oyster Harvest, by Region, 2002 (Millions of 1996 Dollars, Percent of U.S. Harvest Value)



The regional pattern in oyster harvests is longstanding. The Gulf of Mexico and the Pacific have been the dominant oyster production regions since the mid-1980's while other regions have produced a relatively small share of the U.S. annual production (Figure 2-5).

Harvests in the South Atlantic, Middle Atlantic, and New England states, which collectively produced less than 2 million pounds of oyster meat in 2002, have generally comprised a relatively small share of U.S. commercial output. The commercial oyster harvest in the Middle Atlantic has fallen from 2.54 million pounds in 1980 to 1.05 million pounds in 2002. In the South Atlantic, oyster production has declined from 2.29 million pounds in 1980 to 550 thousand pounds in 2002. The commercial oyster harvest in New England rose from roughly 1 million pounds in 1980 to 5.1 million pounds in 1994, but has since dropped to 1 million pounds in 1999 and 314 thousand pounds in 2002.

Figure 2-5. U.S. Commercial Oyster Harvest, by Region: 1980- 2002



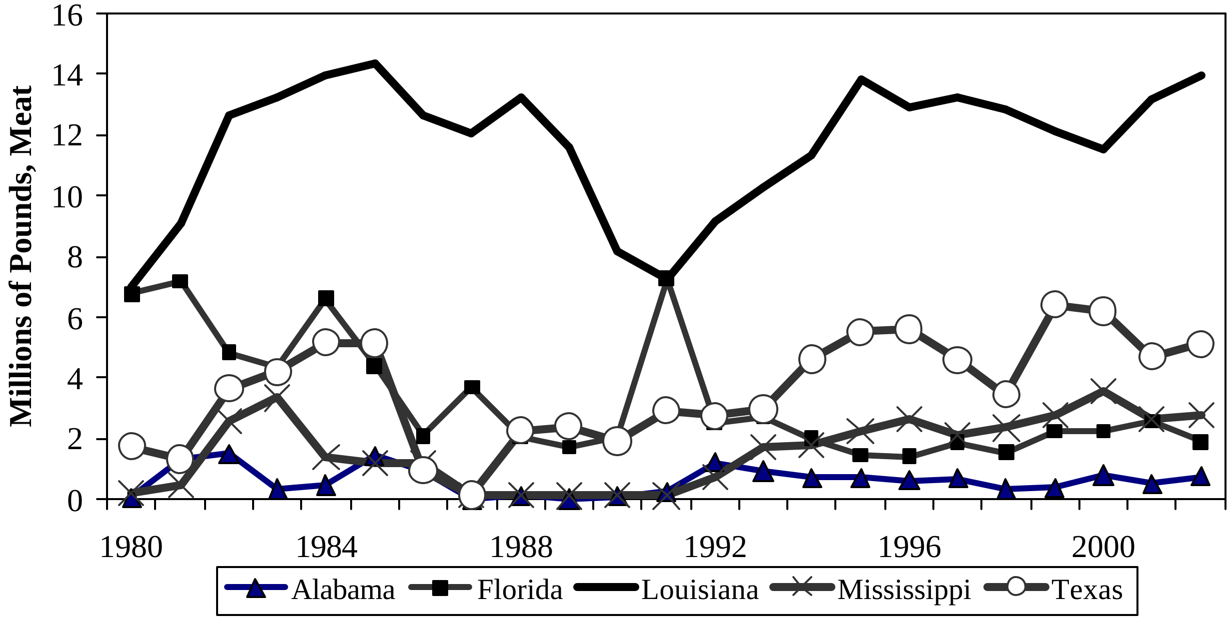
Commercial oyster production in the Pacific region, concentrated in Washington, rose from 6.37 million pounds in 1980 to 10.78 million pounds in 1989. Production has fluctuated between 7 and 10 million pounds since 1990.

The Chesapeake Bay region (Virginia and Maryland), once the leading oyster producing region, has experienced a marked decline. Due to a combination of harvesting pressure and adverse environmental conditions, the Chesapeake Bay oyster harvest has declined from 22,791,110 pounds in 1980 (45 percent of total oyster harvest) to a nadir of 571,000 pounds in 1993. Harvests subsequently rose as high as 2.79 million pounds in 1999 but have declined in each subsequent year to 664,182 pounds in 2002 (1.9 percent of U.S. oyster production).

In contrast, oyster harvests in the Gulf of Mexico have risen from 15.5 million pounds in 1980 and 19.5 million pounds in 1981 to 24.6 million pounds in 2000 and 24.5 million pounds in 2002. Gulf of Mexico oyster production amounted to 31 percent of the U.S. oyster harvest in 1980 and 65.2 percent in 2001 and 70.5 percent in 2002.

The increase in the Gulf oyster harvest has largely matched the increase in Louisiana oyster harvests (Figure 2-6). Louisiana oyster harvest was 6.9 million pounds in 1980 and 9.1 million pounds in 1981. In 2000 Louisiana oyster harvest totaled 11.5 million and in 2002, 13.99 million pounds. The Louisiana oyster harvest was 58.7 percent of the Gulf harvest in 1980 and 57.2 percent in 2002. As a percentage of the national harvest, the state harvest rose from 13.8 of all U.S. oysters in 1980 to 40.3 percent in 2001.

Figure 2-6. Gulf of Mexico Commerical Oyster Harvest, by State: 1980 - 2002



Harvest by Oyster Species

The previous discussion of oyster production pertained to the combined commercial harvest of all species of oysters (phylum *Mollusca*, class *Bivalva*, and family *Ostreidae*). This section will examine separately the volume and value of the four species of oysters harvested commercially in 2001: the American oyster (*Crassostrea virginica*), the Pacific oyster (*Crassostrea gigas*), the Olympia oyster (*Ostreola conchaphila*), and the European flat oyster (*Ostrea edulis*).

In 2002, the American oyster harvest (27,025,155 pounds) represented 77.9 percent of the volume (Figure 2-7) and 71.8 percent of the value (Figure 2-8) of the total commercial oyster harvest. The Pacific oyster harvest (7,668,617 pounds) was 22.09 percent of the total volume. The harvest of European flat oysters (16,950 pounds) and Olympia oyster (3,282 pounds) combined for less than one-tenth of one percent of the commercial harvest volume.

Figure 2-7. Volume of U.S. Commercial Oyster Harvest, by Species, 2002

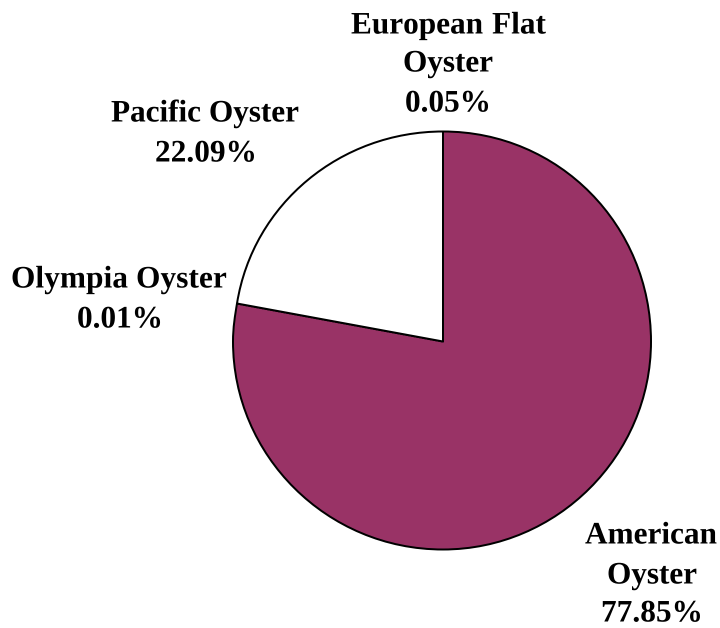
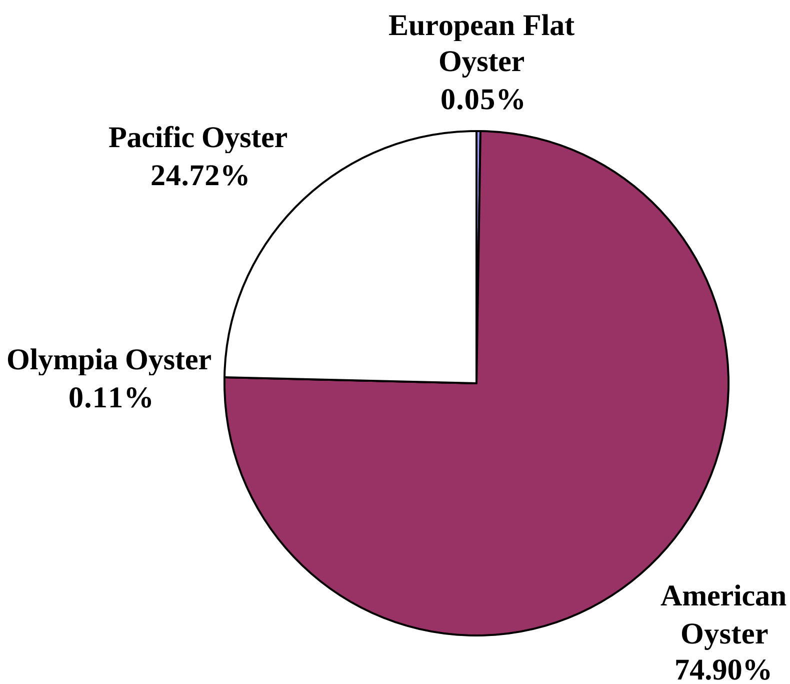
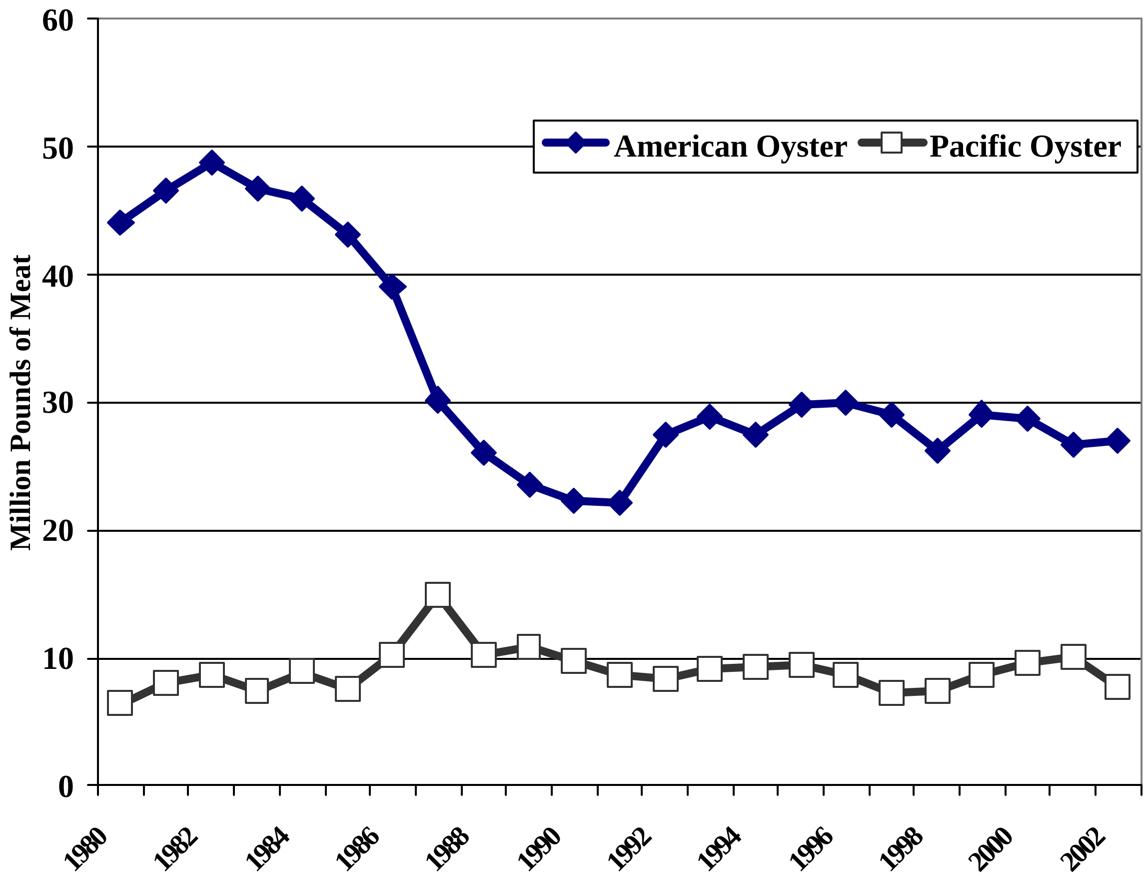


Figure 2-8. Value of U.S. Commercial Oyster Harvest , by Species, 2002



Historically there has been a shift in the species composition of the U.S. commercial oyster harvest, to wit, a rise in the Pacific oyster harvest's share of the overall oyster harvest and a concurrent decline in the volume and share of the American oyster harvest (Figure 2-9). The increase in the share of U.S. oyster production appropriated to Pacific oysters appears attributable less to a sizeable increase in the harvest of Pacific oysters than to a decrease in the volume of eastern oyster harvest associated with the decline in Chesapeake Bay oyster production.

Figure 2-9. Commercial Harvests of American and Pacific Oysters, by Volume: 1980 - 2002



When seafood production is categorized by species (instead of for all species combined as in Table 2-1), the American oyster ranked fifteenth among all commercially harvested seafood in the U.S. (Table 2-2) in 2002, after seven species of crustaceans, one species of bivalve, and six species of finfish. The Pacific oyster ranked twenty-seventh among seafood species harvested in the U.S.

The American oyster (the only species of oyster harvested in the Gulf) ranked fourth in the Gulf of Mexico (Table 2-3) and fifth in the state of Louisiana (Table 2-4).

Table 2-2. Top Fifteen Seafood Species, U.S., by Dockside Value, 2002

Rank	**Seafood Species**	**Pounds (Millions)**	**Dockside Value (Millions of 1996 Dollars)**
1	American Lobster	81.01	260.06
2	Walleye Pollock	3,341.83	184.10
3	Sea Scallop	53.04	184.01
4	Brown Shrimp	128.85	183.31
5	White Shrimp	95.56	164.58
6	Pacific Halibut	81.00	126.66
7	Blue Crab	174.22	118.27
8	Brine Shrimp	47.22	109.21
9	Atlantic Menhaden	1,749.24	94.93
10	Pacific Cod	512.83	86.94
11	King Crab	16.79	76.59
12	Dungeness Crab	48.98	72.37
13	Sablefish	40.90	70.70
14	Sockeye Salmon	135.92	69.86
15	**American Oyster**	**27.03**	**60.14**
Source: National Marine Fisheries Service, 2003			

Table 2-3. Top Fifteen Seafood Species, Gulf of Mexico, by Dockside Value, 2002

Rank	Seafood Species	Pounds (Millions)	Dockside Value (Millions of 1996 Dollars)
1	Brown Shrimp	119.67	165.55
2	White Shrimp	81.95	138.34
3	Atlantic Menhaden	1,284.17	70.63
4	**American Oyster**	**24.46**	**46.51**
5	Blue Crab	69.79	38.32
6	Pink Shrimp	16.41	27.72
7	Florida Stone Crab Claws	6.43	20.86
8	Caribbean Spiny Lobster	4.07	17.06
9	Red Grouper	6.938	11.54
10	Yellowfin Tuna	4.25	11.38
11	Red Snapper	4.78	9.62
12	Other Marine Shrimp	3.01	7.76
13	Striped Mullet (Liza)	12.27	7.67
14	Crawfish	15.60	7.30
15	Gag	3.09	6.57
Source: National Marine Fisheries Service, 2003			

Table 2-4. Top Fifteen Seafood Species, Louisiana, by Dockside Value, 2002

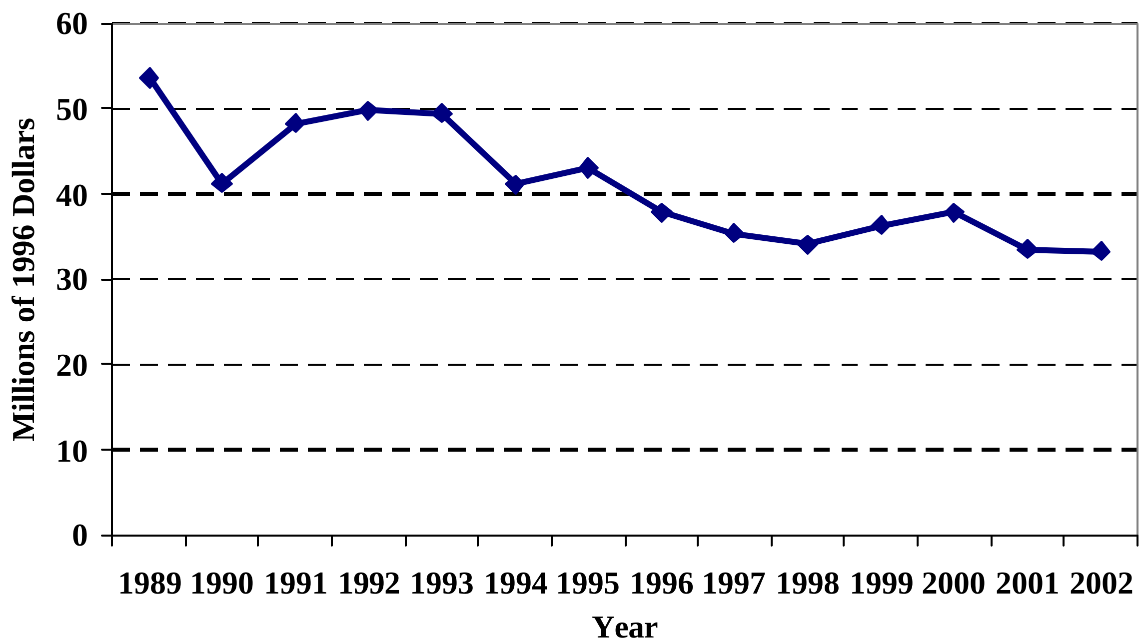
Rank	Seafood Class	Pounds (Millions)	Dockside Value (Millions of 1996 Dollars)
1	White Shrimp	46.63	68.86
2	Atlantic Menhaden	1,087.76	60.00
3	Brown Shrimp	52.69	54.65
4	Blue Crab	53.98	27.72
5	**American Oyster**	**13.96**	**27.36**
6	Yellowfin Tuna	3.41	9.34
7	Crawfish	15.60	7.30
8	Red Snapper	2.16	4.19
9	Seabob Shrimp	6.80	2.25
10	Striped Mullet (Liza)	2.56	1.52
11	Black Drum	3.12	1.46
12	Swordfish	0.70	1.32
13	Blue Catfish	3,134.76	1.28
14	Vermilion Snapper	0.75	1.18
15	King Mackerel	0.87	0.95
Source: National Marine Fisheries Service, 2003			

Box A. Oyster Product Imports

The U.S. imports millions of dollars of oyster products annually. Most are in a different product form than domestic oyster products and arguably fill a different market niche. Data provided by the U.S. Customs Service and the National Oceanic and Atmospheric Administration (N.O.A.A.) Fisheries Statistics and Economics Division reveals a decline in the real (inflation-adjusted) value of oyster product imports (Figure 2-10) from over $50 million (1996 dollars) in 1989 to $33.3 million in 2002.

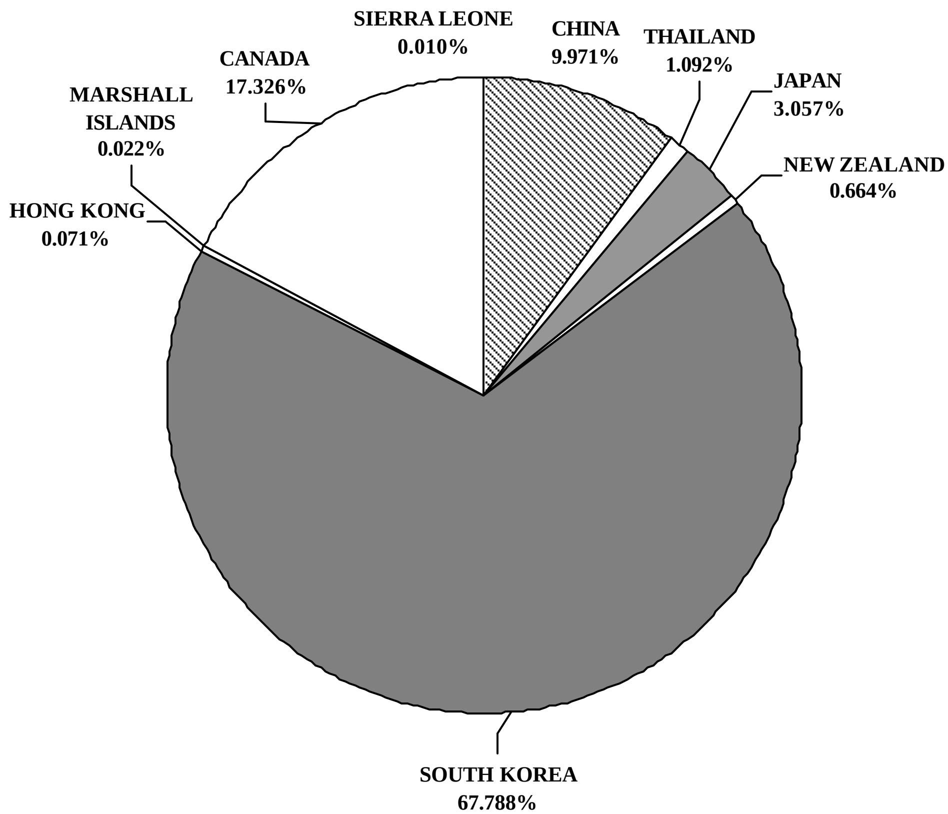
The largest producer of imported oyster products is South Korea, origin of over two-thirds of the value (Figure 2-11) of all oyster product imports in 2002. Roughly half of oyster product imports enter the U.S. through Pacific coast ports and approximately 20 percent enter through ports in the Mid-Atlantic (Virginia through New York).

Figure 2-10. Value of Oyster Imports: 1989 - 2002



Box A. Oyster Product Imports (Continued)

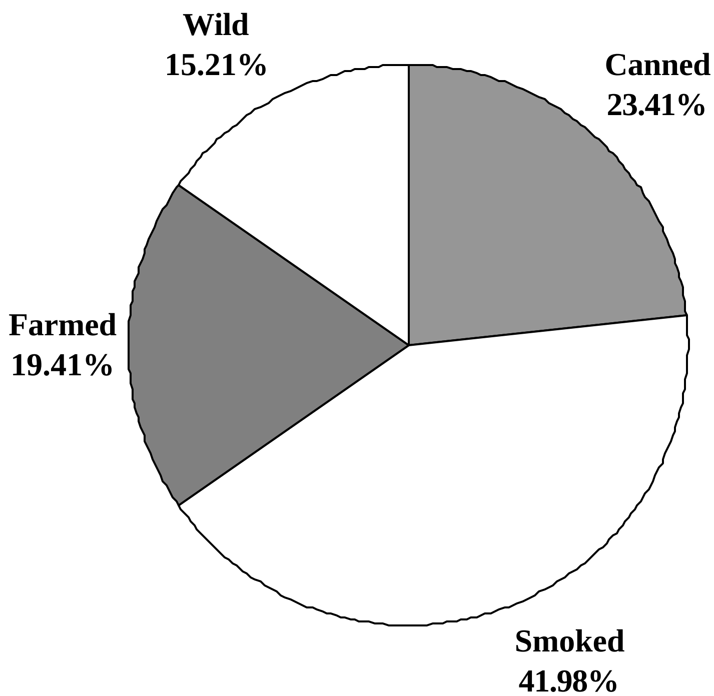
Figure 2-11. Country of Origin for Oyster Imports, by Value: 2002



The N.O.A.A. Fisheries Statistics and Economics Division identified four major categories of oyster product imports: canned, smoked, farmed (live/fresh/frozen/dried/salted/brine), and wild (live/fresh/frozen/dried/salted/brine). In 2002, smoked oysters had the largest share (41.98 percent) of the total value of imported oyster products (Figure 2-12). The value per unit of volume is higher among smoked canned oysters ($5.27 per kilo [$2.39 per pound] in 2002 dollars; $4.76 per kilo [$2.10 per pound] in 1996 dollars) than among canned oysters ($2.99 per kilo [$1.36 per pound] in 2002 dollars; $2.70 per kilo [$1.22 per pound] in 1996 dollars). Wild oyster products had a value of $6.33 per kilo [$2.87 per pound] ($5.72 per kilo [$2.59] in 1996 dollars). Farmed oyster products had a per kilo value of $3.79 [$1.72 per pound] ($3.42 in 1996 dollars [$1.55 per pound].)

Box A. Oyster Product Imports (Continued)

Figure 2-12. Value of Imports, by Product: 2002



The value of oyster imports in 2001 ($33.3 million in 1996 dollars) was 41.4 percent of the dockside value of the domestic oyster harvest ($80.3 million in 1996 dollars). The comparison of the value of imports and commercial harvests is difficult to interpret because the products are essentially different goods. Imported oysters reflect the value of a variety of products that are more or less already in the same form in which they will be presented to the final consumer. The domestic commercial harvest is the value of a raw product, fresh oysters, which may undergo significant transformation of form (i.e., processing) and enhancement of value before reaching the final consumer.

Louisiana Oyster Harvest by Parish

Commercial harvest of oysters in Louisiana (12.87 million pounds of meat) occurred in 10 coastal parishes in 2001 (Figure 2-13). The most productive oyster areas are located in the southeastern section of the state. Nearly three-quarters (9,411,583 pounds) of the oysters harvested originated in three parishes: in ascending order, Plaquemines, Terrebonne, and Saint Bernard parishes (Figure 2-14). Two of these parishes (Plaquemines and Terrebonne) have appeared among the "top three" harvesting parishes each year since 1980 (Table 2-5).

Figure 2-13. Parishes Reporting Commercial Oyster Harvests, 2001

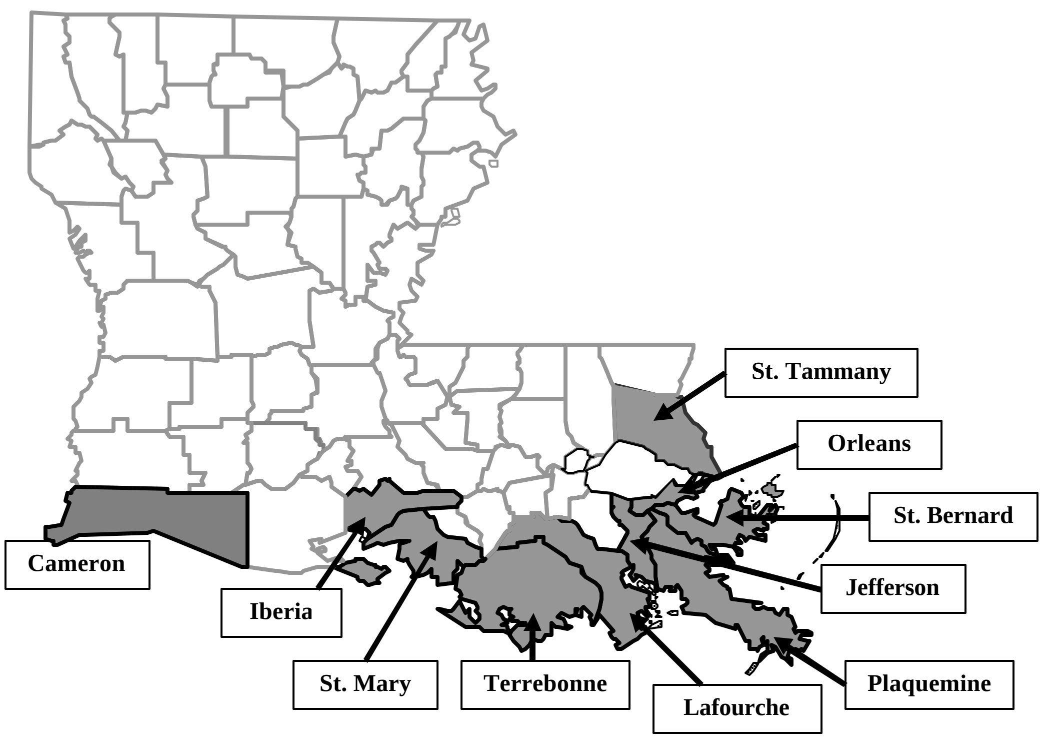
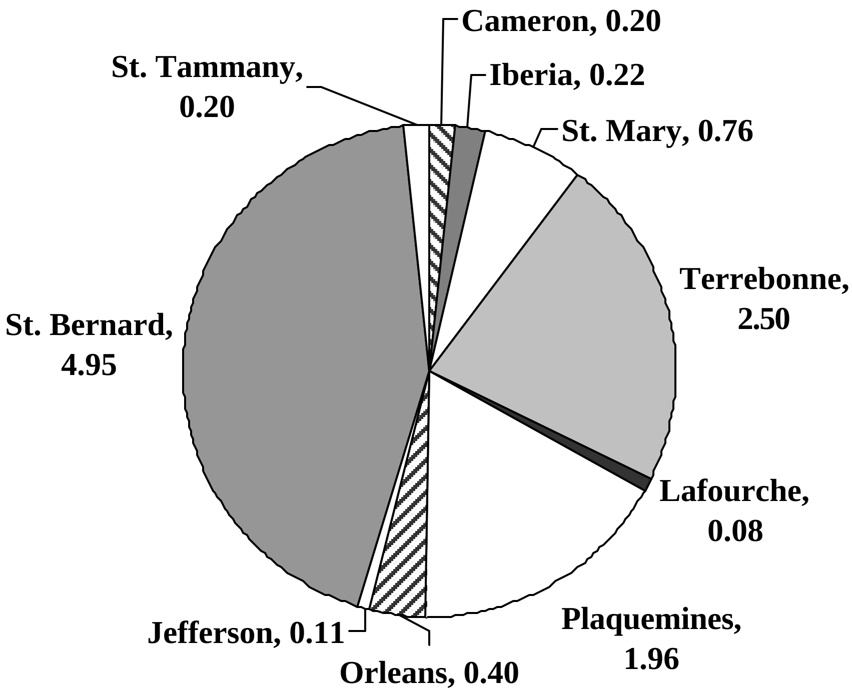


Figure 2-14. Commercial Harvest by Parish, 2001
Millions of Pounds



Shifts in the Utilization of Public and Private Reefs in Louisiana

Louisiana's vast and extensive private oyster grounds (those leased from the state with 15-year leases) have traditionally been a rich source of commercial oysters. The average annual harvest from private leases from 1991 to 2001 was 6,524,184 pounds, ranging from a low of 5,452,317 pounds in 1993 to a high of 7,895,394 pounds in 1998. The average annual harvest from private leases was somewhat higher in the previous 11 years (1980 – 1990): 8,207,407 pounds. The lowest annual harvest for this period was 7,005,308 pounds in 1981; the highest was 10,968,224 pounds in 1988.

Since 1990, harvests from public oyster grounds have generally increased (Figure 2-15). The average annual harvest from public reefs for the eleven-year period from 1991 to 2001 was 5,014,325, higher than the average annual public reef harvest for the 1980 to 1990 period: 2,622,420 pounds.

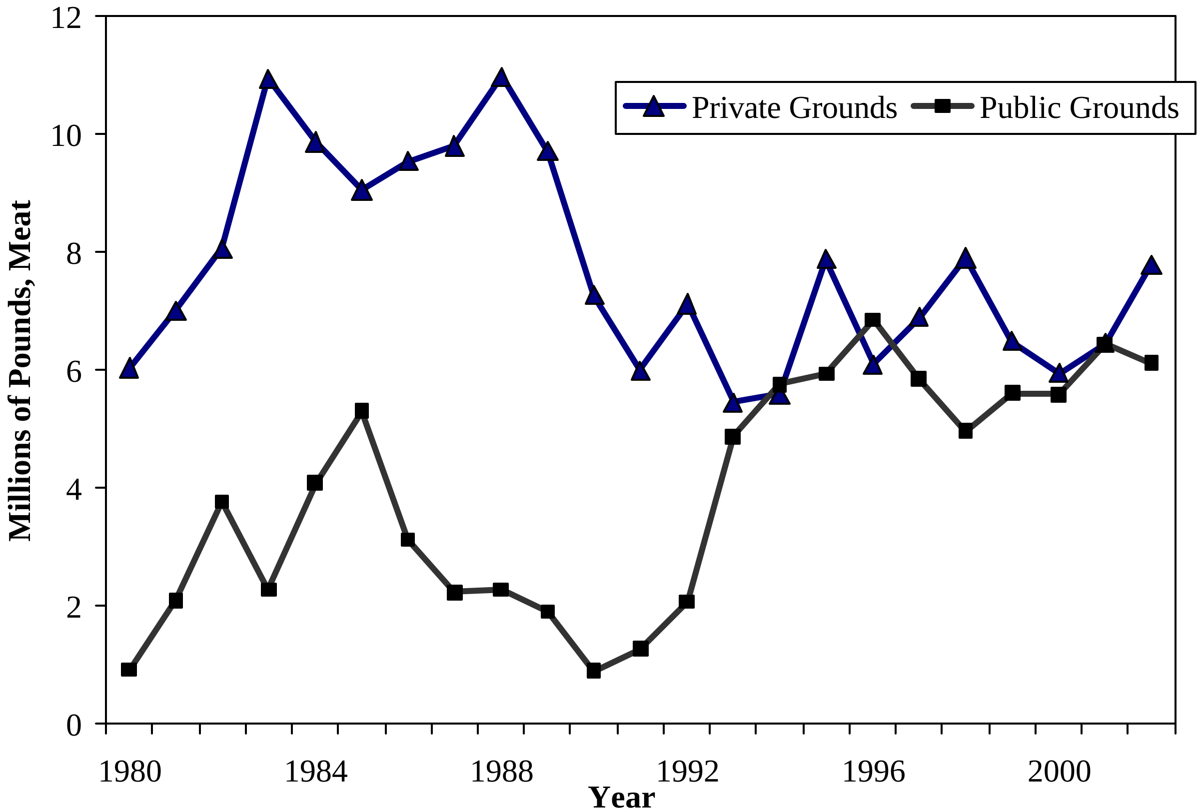
Table 2-5. Three Most Productive Parishes for Commercial Harvests of Oysters in Louisiana, by Year: 1980 – 2001

Year	First	Second	Third	Combined Percentage of State Harvest
1980	Plaquemines	Terrebonne	Lafourche	70.5
1981	Plaquemines	Terrebonne	Lafourche	66.6
1982	Plaquemines	St. Bernard	Terrebonne	79.1
1983	Plaquemines	St. Bernard	Terrebonne	77.3
1984	Plaquemines	Terrebonne	Lafourche	78.9
1985	Plaquemines	Terrebonne	St. Bernard	85.0
1986	Plaquemines	Terrebonne	St. Bernard	87.7
1987	Plaquemines	Terrebonne	Lafourche	80.8
1988	Plaquemines	Terrebonne	Lafourche	75.5
1989	Plaquemines	Terrebonne	St. Mary	69.9
1990	Plaquemines	Terrebonne	Lafourche	80.7
1991	Plaquemines	Terrebonne	St. Bernard	77.9
1992	Plaquemines	St. Bernard	Terrebonne	73.4
1993	Plaquemines	St. Bernard	Terrebonne	80.4
1994	Plaquemines	St. Bernard	Terrebonne	76.1
1995	Plaquemines	Terrebonne	St. Bernard	70.0
1996	Plaquemines	Terrebonne	St. Bernard	74.1
1997	Plaquemines	St. Bernard	Terrebonne	74.7
1998	Plaquemines	Terrebonne	St. Bernard	74.2
1999	Plaquemines	St. Bernard	Terrebonne	76.0
2000	St. Bernard	Plaquemines	Terrebonne	77.4
2001	St. Bernard	Terrebonne	Plaquemines	73.1

Source: Louisiana Department of Wildlife and Fisheries

This combination of decreased harvests from private leases and increased harvests from public oyster grounds suggests a shift in the utilization of public and private reefs. From 1980 to 1990, 70.6 percent of the total commercial oyster harvest came from private leases. In contrast, only 56.5 percent of total harvests between 1991 and 2001 came from private grounds.

Figure 2-15. Quantity of Commercially Harvested Oyster Meat from Public and Private Grounds in Louisiana: 1980 - 2002



The relative shift from private to public oyster grounds has been especially pronounced since 1990. In 1991, 82.5 percent of the commercial oyster harvest originated from private grounds. In 2001, the portion of commercial oysters from private leases had dropped to 50.1 percent. This change in the private-public harvest mix does not stem so much from a decrease in the use of private reefs as from an increase in the use of public grounds. The increase in absolute harvest from public reefs from 1990 to 2000 has been larger than the corresponding decrease in the harvest from private reefs.

Estimating the Quantity of Shell Removed from Louisiana's Public Reefs

The Louisiana Department of Wildlife and Fisheries has a long history of planting cultch, dating back to at least 1917 when the state deposited 21,882 cubic yards of unspecified cultch on 729 acres. There were two plants totaling 8,453 cubic yards on 284 acres between 1919 and 1929. In the 1930's, nine plantings (67,366 cubic yards) were placed on 2,245 acres. In the 1940's, 83,941 cubic yards (seven plantings) were deposited on 2,762 acres. Five plantings, totaling 66,723 cubic yards on 2,222 acres, were accomplished during the 1950's. Deposits of cultch on public oyster reefs rose to 228,904 cubic yards on 6,536 acres in the 1960's and peaked at 335,675 cubic yards on 7,613 acres in the 1970's. The 1980's saw four plantings totaling 191,532 cubic yards over 2,816 acres.

From 1990 to 2001, the Louisiana Department of Wildlife and Fisheries deposited 132,369 cubic yards of cultch on public oyster reefs. During this period, the utilization of public reefs rose and, with it, the rate of removal of cultch material collected incidentally with the shellfish.

From 1990 to 2001, the sum of commercial oyster landings harvested from public reefs was 56,334,587 pounds of meat. A conversion factor provided by the Louisiana Department of Wildlife and Fisheries Marine Fisheries Division can be used to estimate the quantity of oyster shell, a potential form of cultch, removed in the taking of these resources. The National Marine Fisheries Service estimates that there are 6.47 pounds of meat in one sack of oysters. The Louisiana Department of Wildlife and Fisheries estimates that 14.46 sacks of oysters will produce one cubic yard of shell. Thus, every 93.57 pounds of oyster meat generates approximately one cubic yard of shell.

Dividing the volume of harvested meat by the conversion factor (93.57) will provide an estimate of the volume of oyster shells removed with the oysters. With the oysters harvested from public reefs between 1990 and 2001 (56,049,587 pounds of meat), 530,334 cubic yards of oyster shell were removed. Over the same period, the Department deposited 132,386 cubic yards of cultch. In other words, from 1990 to 2001, the excess of the volume of cultch removed over the volume deposited on public oyster grounds was 397,966 cubic yards.

The increasing difference between the removal of oyster shell as cultch and the quantity of cultch deposited on public oyster grounds obviates the need for continued investment in and maintenance of Louisiana's reefs. This research will continue with a discussion of oyster processing in Louisiana and the rest of the Gulf of Mexico (Chapter 2-3) to estimate the economic value of the processing sector and to discuss the availability of oyster shell, a by-product of shucked oyster production.

Chapter 2-3. Oyster Processing in Gulf of Mexico States

The economic contribution of oyster resources extends beyond the dockside value of the commercial harvest to other portions of the marketing chain. There may be many intermediaries between oyster harvesters and seafood consumers. Dealers and wholesalers may purchase oysters from harvesters before reselling them to processors, retailers, restaurants, and consumers. Processors may alter the oysters to a more convenient, attractive, or satisfying form.

Examining the processing sector provides a more complete understanding of the economic impact of the oyster industry. It will also provide insight into the distribution and availability of oyster shell, a desirable cultch material.

The processor data provided in this chapter are derived from the National Marine Fisheries Services (N.M.F.S.) Seafood Processors Survey of firms in states on the Gulf of Mexico. The sample consists of responses from oyster processors who voluntarily provide information including species, product form, volume (in pounds of meat), sales (in current dollars), number of employees, and geographical location. Because compliance is voluntary, the sample may not represent the entire population of seafood processors.

This chapter will discuss the production of fresh shucked oysters in Gulf of Mexico states from 1980 to 2000, the latest year for which data is available. Fresh shucked oysters are the most common form of oyster product[1] in the region and the form most likely to leave, as a by-product, oyster shells that may be used as cultch.

[1] Indeed in most years, fresh shucked oysters are the only oyster product produced by Gulf of Mexico oyster processors.

The Gulf of Mexico is the home of approximately 90 oyster processors, according to N.M.F.S. data, a decline from nearly 180 in 1980 (Figure 2-16). The steepest decline in the number of processors occurred between 1980 and 1990 when the population of processors fell from 150 to approximately 100. Since 1990, there has been a slight decline in the number of oyster processors.

The volume of processed oyster products (primarily fresh shucked oysters) fell from 16 million pounds in 1980 to 11.7 million pounds in 1990. The decline in the number of processors since 1990 (from 104 to 97) has coincided with an erratic increase in the reported volume of processed product (Figure 2-17). The volume of oysters processed in the Gulf rose to 16.4 million pounds in 1997 and then declined to approximately 12.0 million pounds in 1998 and 1999. Production increased dramatically

Figure 2-16. Number of Shucked Oyster Processors in States on the Gulf of Mexico: 1980 - 2000

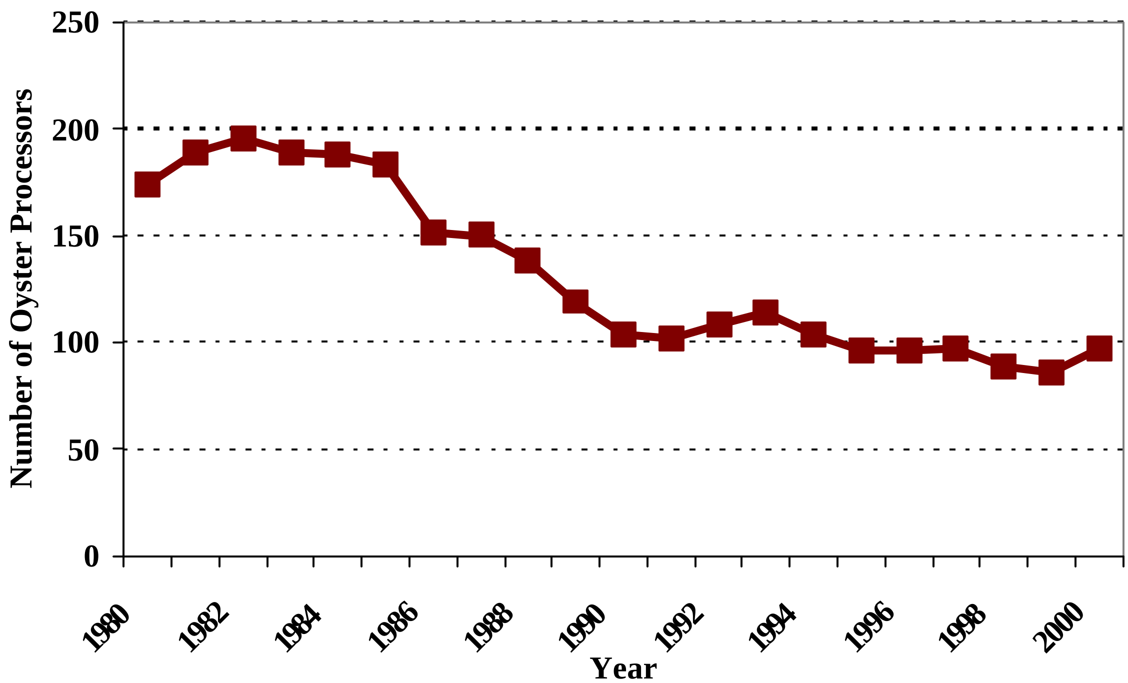
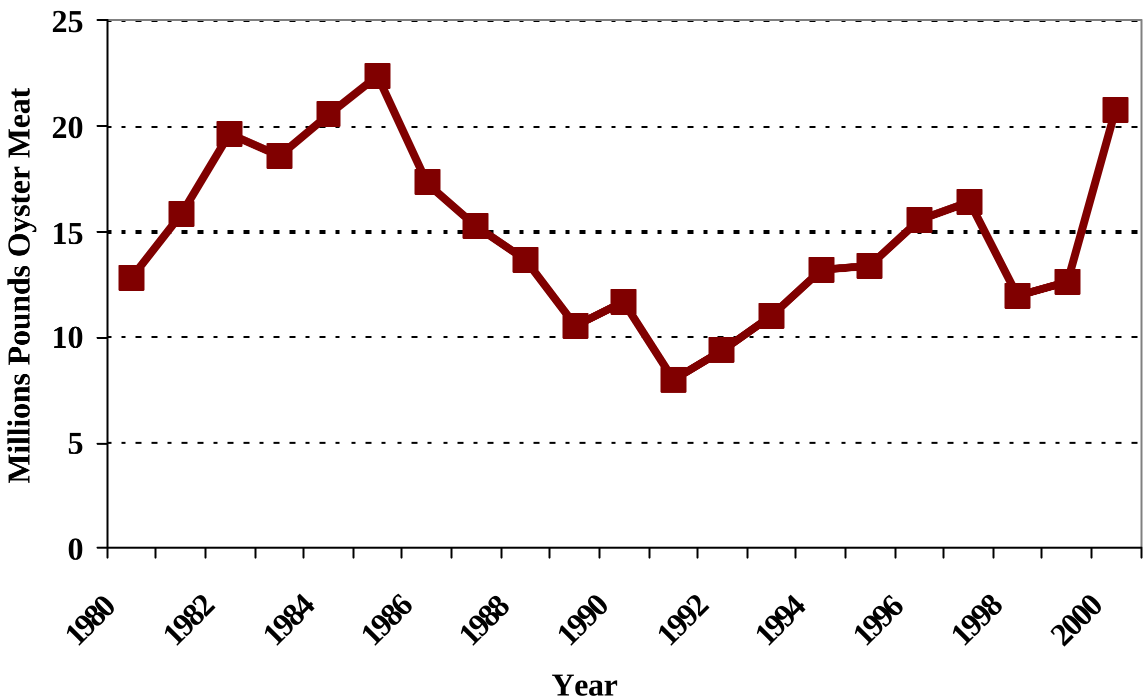


Figure 2-17. Volume of Fresh Shucked Oysters in States on the Gulf of Mexico: 1980 - 2000



to 20.8 million pounds in 2000. It is unknown whether this increase represents a temporary or long-lived change in output.

In the year 2000, Alabama had the largest number of processors among Gulf States, a distinction it has claimed since 1991 (Figure 2-18). Among Gulf States, only Alabama has witnessed an increase in the number of processors over the last two decades (Figure 2-19). The biggest drop has been in Florida, from 46 in 1980 to 11 in 2000. During this same period, the population of processors in Mississippi has fallen from 17 to 7, in Texas from 30 to 16, and in Louisiana from 34 to 19.

Figure 2-18. Number of Shucked Oyster Processors in States on the Gulf of Mexico, by State, 2000

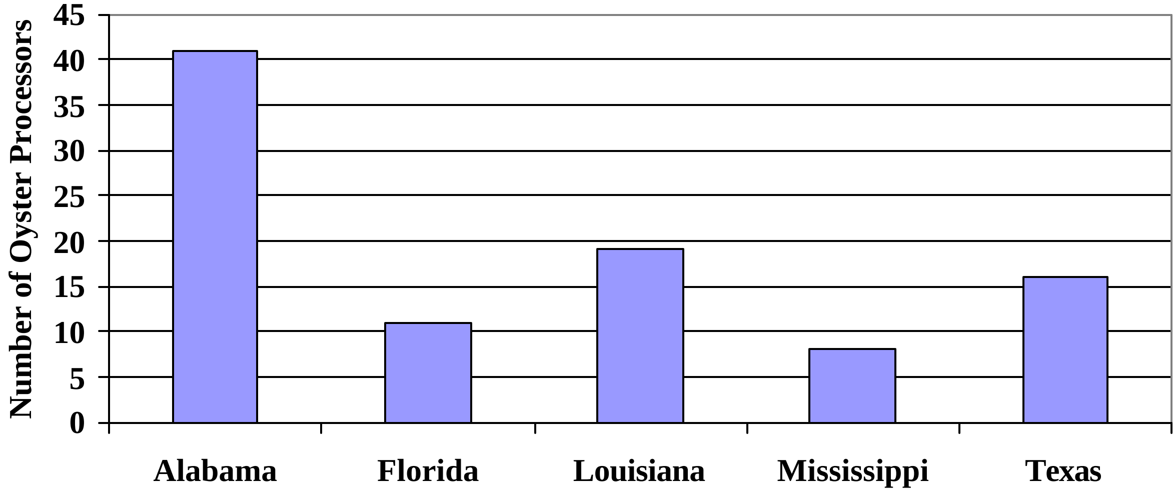
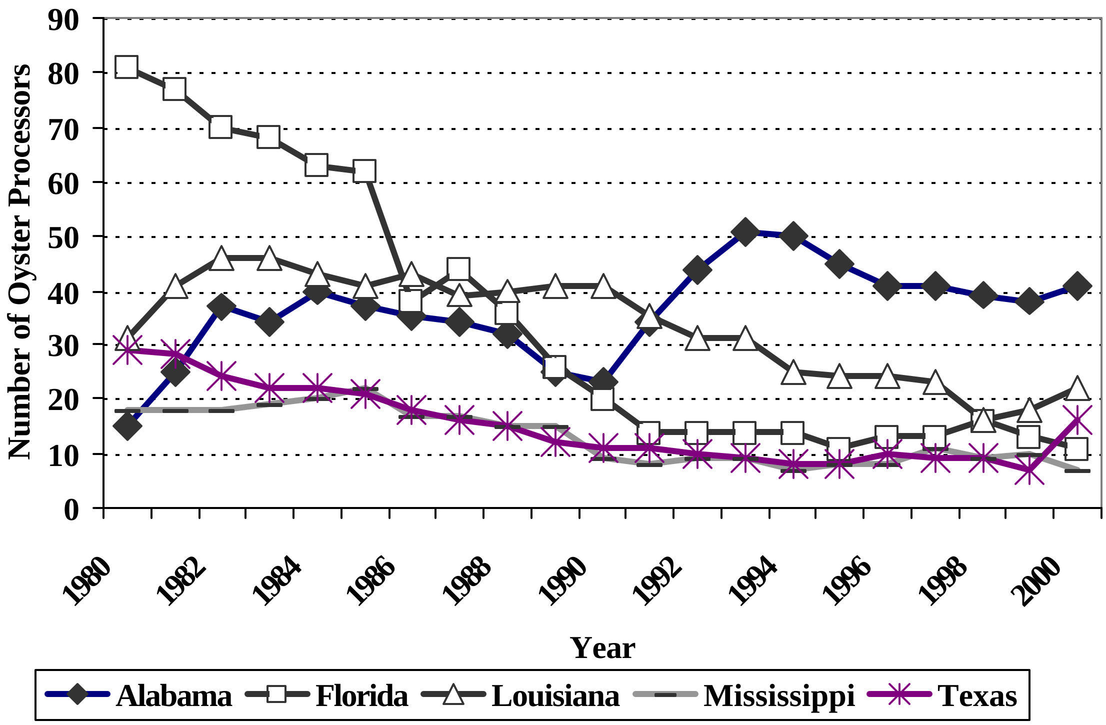
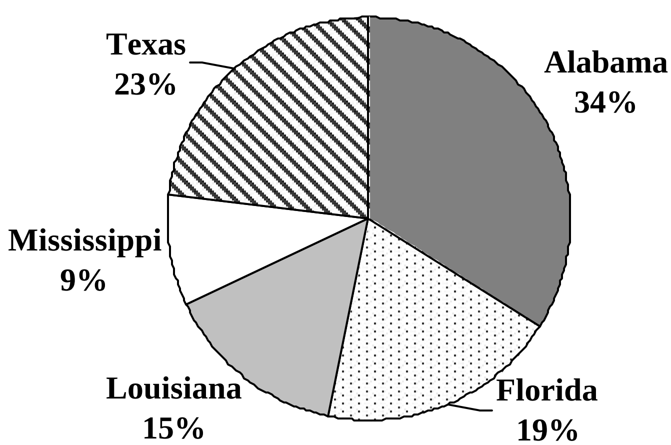


Figure 2-19. Number of Shucked Oyster Processors in States on the Gulf of Mexico, by State: 1980 - 2000



Alabama processes more oysters than any other state in the Gulf, producing over one-third of the volume of processed oysters in the region (Figure 2-20). There have been distinct trends in processing volume in the individual Gulf States for the last twenty years. Alabama has seen a steady increase from 1.4 million pounds in 1980 to 2.0 million pounds in 1989 and 3.6 million pounds in 1990 to 7.1 million pounds in 2000. Florida recorded a decline in processing from 4.7 million pounds in 1980 to 1.1 million in 1989 and 0.75 million in 1990, followed by a rebound to 2.9 million pounds in 1999 and 4.0 million pounds in 2000. Mississippi witnessed a similar pattern, a decrease from 1.3 million pounds in 1980 to 0.53 million in 1990, followed by an increase to 1.9 million pounds in 2000. Louisiana saw an increase in processing volume during the 1980's, from 4.2 million pounds in 1980 to 5.9 million pounds in 1990, with a decrease since 1990 to 3.0 million pounds in 2000. Texas oyster processing, which averaged 0.94 million pounds during the 1990's, reached a historically high of 4.8 million pounds in 2000.

Figure 2-20. Share of the Volume of Oysters Processed in States on the Gulf of Mexico, by State, 2000



Employment

The oyster processors in Gulf of Mexico region employed 1,977 workers in 2000 (Figure 2-21). This reverses a downward trend from 2,861 in 1986 to 1,225 in 1999. From the available data it is impossible to tell if the increase in employment in 2000 is a momentary change or the beginning of an upward trend. The bulk of this increase in Gulf oyster processing employment is attributed to a boost in employee numbers in Texas, from 114 in 1999 to 749 in 2000 (Figure 2-22).

In 2000, Texas (atypically) reported the largest number of employees among the Gulf of Mexico states, followed by Alabama (530) and Florida (268). From 1990 to 1999, Texas was usually third (or lower) among Gulf States behind Louisiana and Alabama, the leading employer for 8 of the last 10 years.

Figure 2-21. Oyster Processor Employment in the Gulf of Mexico Region: 1980 - 2000

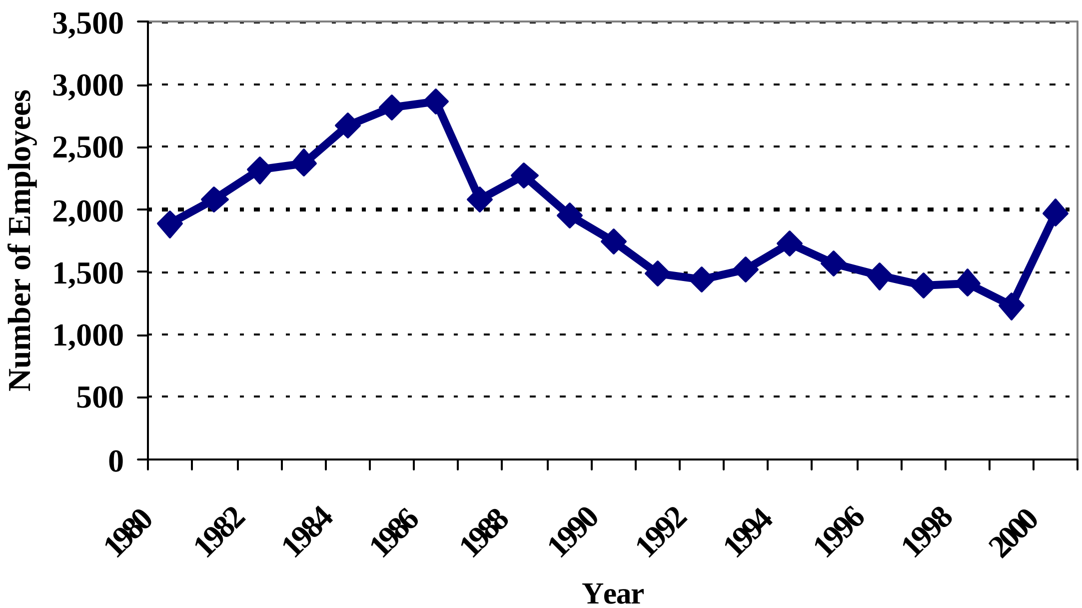
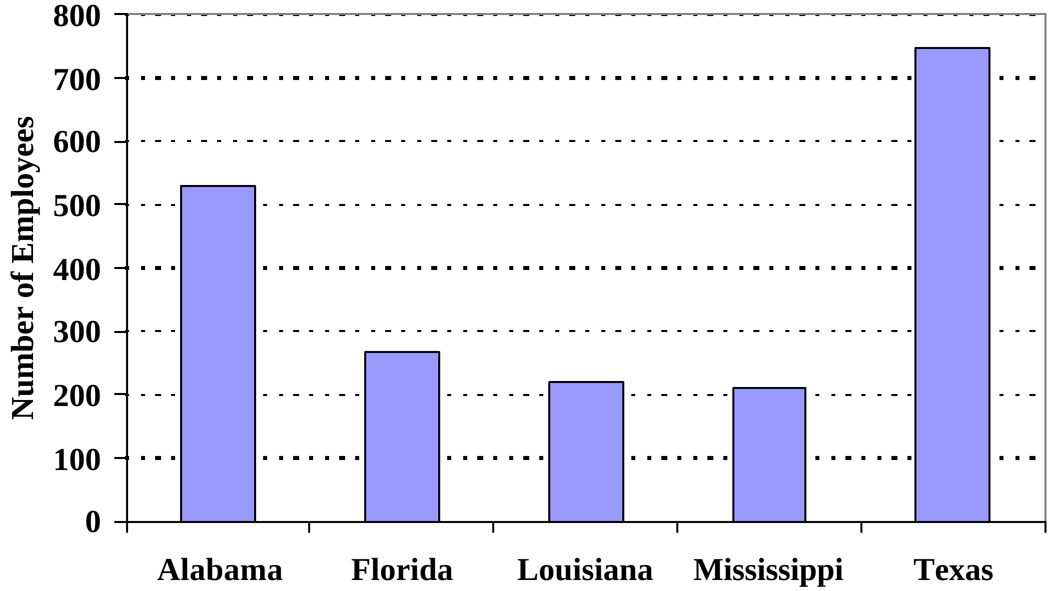


Figure 2-22. Oyster Processor Employment in States on the Gulf of Mexico, by State, 2000

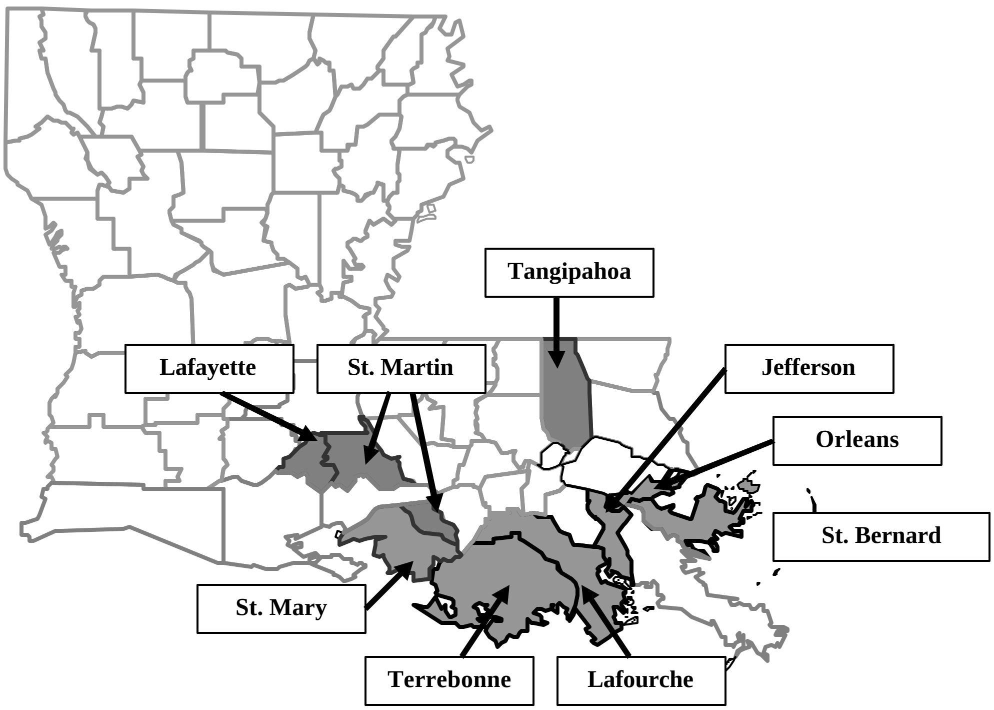


The number of employees in Alabama increased from 369 in 1989 to 684 in 1994, and has since declined to 478 in 1999 and 530 in 2000. Employment numbers in Mississippi and Florida have followed similar trajectories since the mid-1980's, declining from 1987 to 1994 and climbing from 1995 to 2000. The number of processing employees in Louisiana has decreased from 634 in 1994 to 221 in 2000.

Oyster Processing within Louisiana

Commercial oyster processing plants responding to the N.M.F.S. Seafood Processors Survey were located in eight Louisiana parishes in 2000 (Figure 2-23). There were six reporting firms in the metropolitan New Orleans area (in Jefferson, Orleans, Saint Bernard, and Tangipahoa) and thirteen reporting firms in five south central Louisiana parishes (Lafayette, Lafourche, Saint Martin, Saint Mary, and Terrebonne.)

Figure 2-23. Louisiana Parishes Containing At Least One Processor in N.M.F.S. Seafood Processor Survey, 2001



The geographical distribution of oyster processing firms in Louisiana is more dispersed than in most other Gulf States. In contrast to the wide dispersion in Louisiana, all of Alabama's processors were located in one county (Mobile). All of the oyster processing plants in Florida were located in two counties (Franklin and Bay), as were those in Mississippi (Jackson and Hamilton).

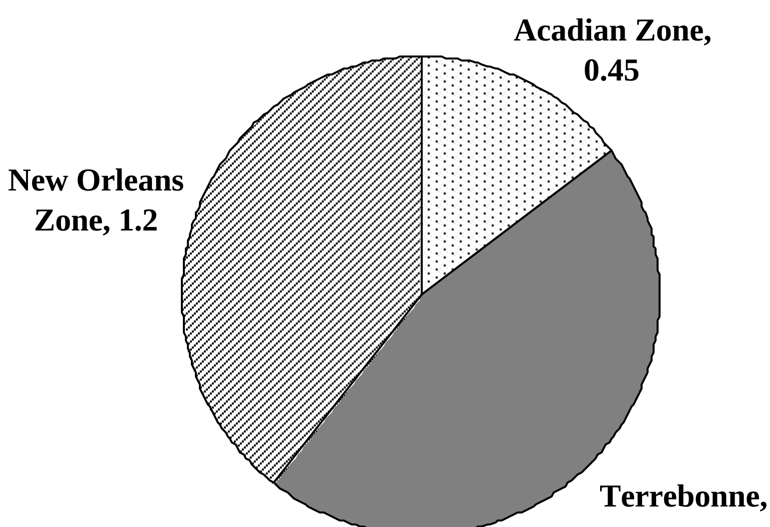
Confidentiality agreements with the N.M.F.S. forbid the publication of regional level data if the designated area contains fewer than three reporting firms. The Louisiana Department of Wildlife and Fisheries Socioeconomic Research and Development Section prefers not to discuss data if the region contains fewer than five reporting firms. Only one parish contained five or more reporting firms in 2000 - Terrebonne Parish, whose six processors reported 1.38 million pounds of fresh shucked oyster meat.

In order to report processing data at a level lower than statewide total (other than Terrebonne Parish), this report combines the remaining reporting processors into two zones made up of several parishes (Table 2-6). Processors in the four parishes in metropolitan New Orleans (Orleans, Jefferson, Saint Bernard, and Tangipahoa) produced 1.2 million pounds of oyster meat (Figure 2-24). Processors in the "Acadian Zone", a collection of four parishes west of New Orleans excluding Terrebonne Parish, produced 0.45 million pounds in 2000.

Table 2-6. Parishes Containing Oyster Processor Plants in 2000, by Designated Zones

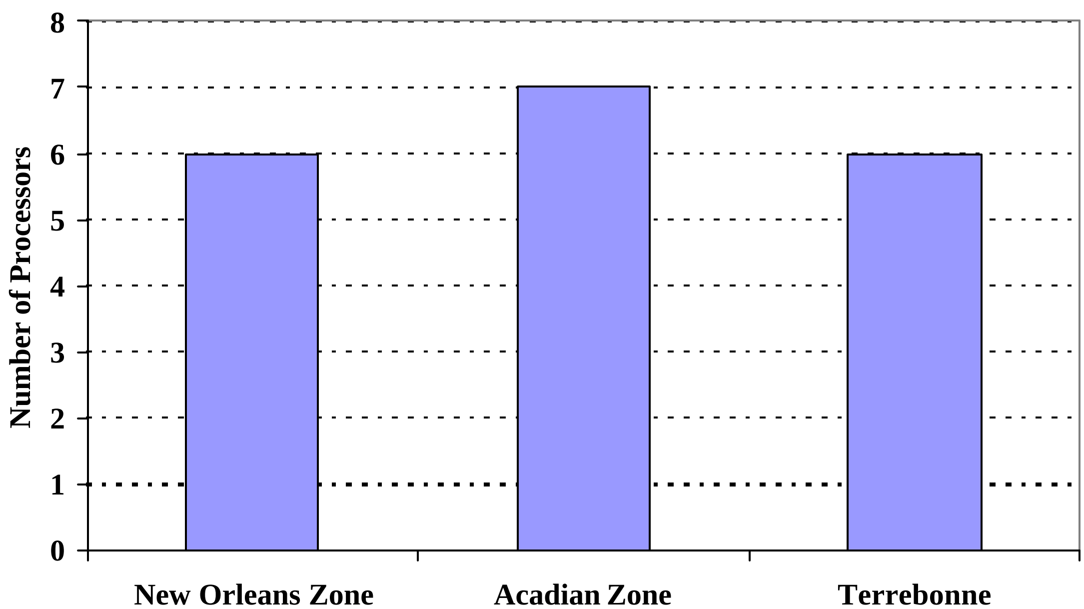
Acadian Zone			
Lafayette	Lafourche	Saint Martin	Saint Mary
Terrebonne			
Terrebonne			
New Orleans Zone			
Jefferson	Orleans	Saint Bernard	Tangipahoa

Figure 2-24. Volume of Oyster Processing within Designated Zones, 2000 (Millions of Pounds of Meat)



Over the last twenty years, the number of processors in the New Orleans area has declined from thirty firms in 1984 to six processors in 2000 (Figure 2-25). The number of firms in Terrebonne Parish has dropped from thirteen in 1990 to six in 2000. The number of firms outside Terrebonne Parish and the New Orleans area was seven in 2000 and has remained relatively stable since the 1980's.

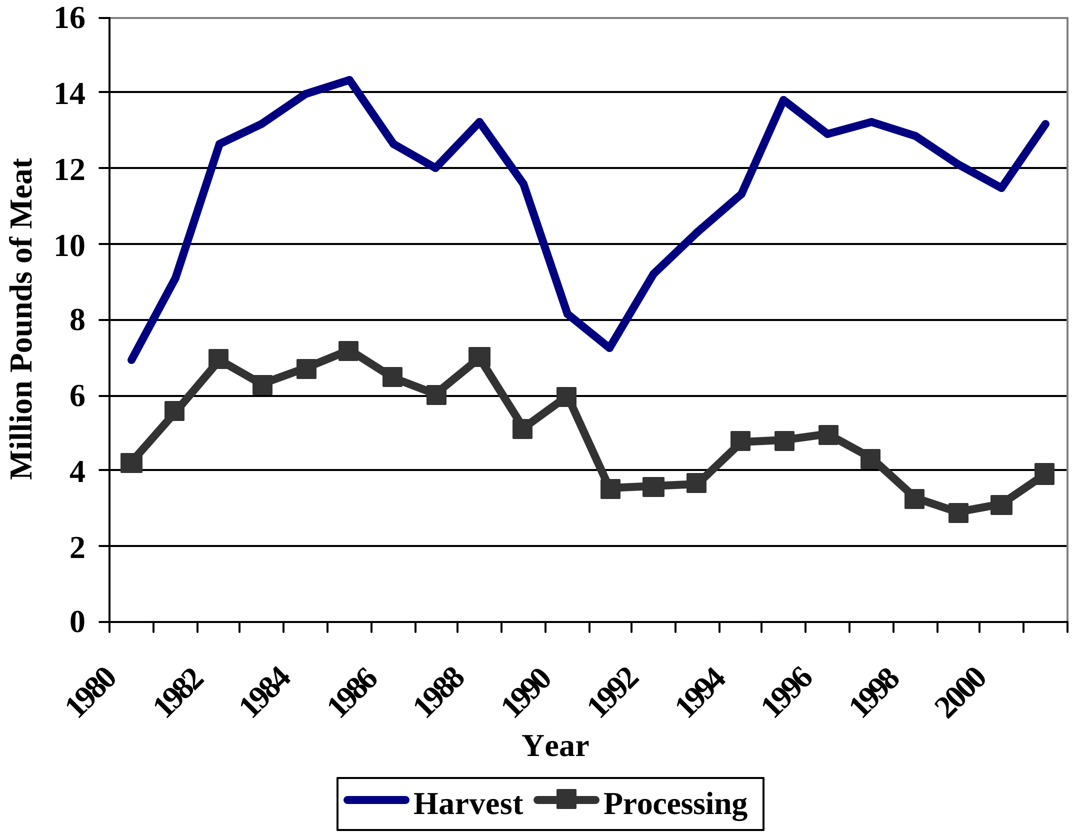
Figure 2-25. Number of Oyster Processors in Louisiana, by Designated Zone: 2000



Comparing Commercial Oyster Harvesting and Processing in Louisiana

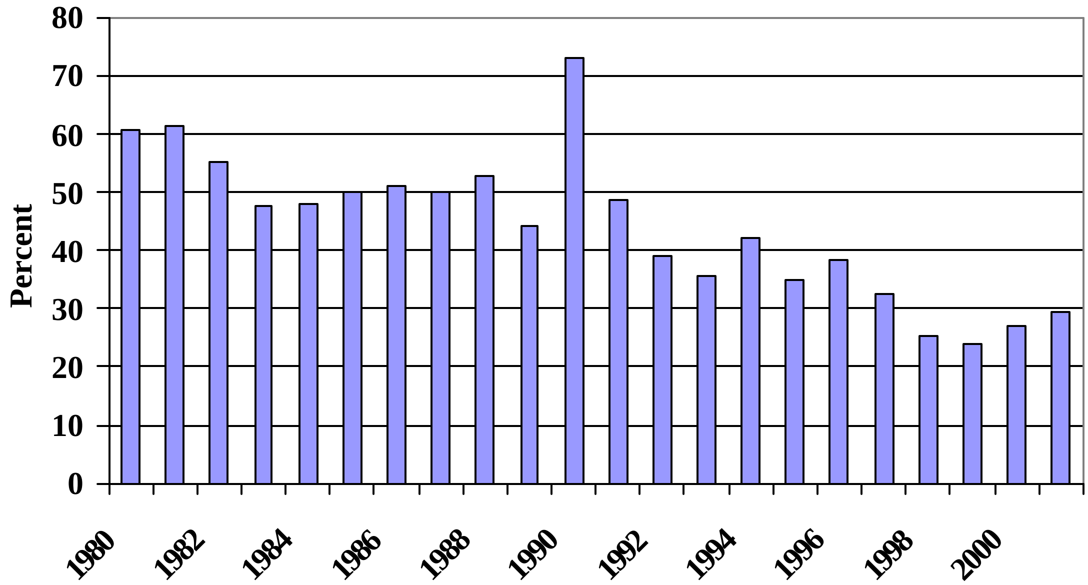
Historically, the commercial oyster harvest in Louisiana has been larger than the volume of oysters processed within the state. In 2000, the excess of harvest over processed volume was approximately 9 million pounds. The difference has widened over the past ten years as harvests increased and the volume of processing declined (Figure 2-26).

Figure 2-26. Excess of Harvests over Processing, Louisiana: 1980 - 2001



In 2000, the ratio of Louisiana oyster processing to Louisiana commercial oyster harvest was 0.269, somewhat higher than the ratios for 1998 and 1999, but lower than the processing-harvest ratio for most of the 1990's (Figure 2-27). The processing-harvest ratios for 1990 (0.73) and 1991 (0.486) were relatively high probably because harvests were relatively low in those years.

Figure 2-27. Processing in Louisiana as a Percentage of Commercial Harvest: 1980 - 2001



Louisiana Department of Wildlife and Fisheries Oyster Processor Survey

The Louisiana Department of Wildlife and Fisheries Socioeconomic Research and Development Section sought to augment the N.M.F.S. Seafood Processor Survey (N.M.F.S. Survey) with its own survey of processing plants within Louisiana. The Louisiana Department of Wildlife and Fisheries Oyster Processor Survey (henceforth, Louisiana Processor Survey) included many items not included in the N.M.F.S. Survey including inquiries about daily and seasonal production, shell availability, stockpiling, and disposal. A questionnaire was mailed in August, 2000 to all 32 processors listed in the Interstate Certified Shellfish Shippers List maintained by the U.S. Department of Health and Human Service, Food and Drug Administration. The initial questionnaire mailing was followed by a reminder postcard and an additional copy of the survey to all who had not yet responded. Seventeen surveys were returned for a 53 percent response rate.

The geographical distribution of the Louisiana Processor Survey was different from that of the N.M.F.S. Survey in 2000. The Louisiana Processor sample, for example, includes respondents from two parishes from which the N.M.F.S. Survey contained no respondents: one each from East Baton Rouge and St. Tammany Parishes. While the N.M.F.S. Survey included one respondent from Tangipahoa Parish, the Louisiana Processor survey reported three. The N.M.F.S. reported six respondents from Terrebonne Parish and one from Jefferson Parish. The Louisiana Processor Survey reported only three from Terrebonne Parish and none from Jefferson Parish.

The average daily output of the processors who responded to the Louisiana Processor survey was 105 sacks per day, generating an average of 10 cubic yards of shell per day. The fourth quarter (October through December) was the busiest season of the year (in terms of quantity of oysters processed) for eight processors. The first quarter (January through March) was the busiest season for another eight. The third quarter (July though September) was the least busy season for twelve; the first quarter the least busy for three processors.

Ten of the seventeen respondents desired daily pick-up of their shell. Six of the seventeen transported the shell themselves, twelve had somebody else transport them. Two respondents transported the shells and also had somebody else haul them away. Only two respondents in 2000 had a contract with somebody to pick up the shells.

Five respondents paid for the hauling away of their oyster shells "in kind", allowing the hauler to keep the shells. One gave the transporter the shell and $50 per week. One paid a transporter $7 per cubic yard to take the shell away.

The average estimated distance over which shells were transported was 7.25 miles. The minimum was one mile; the maximum 38 miles.

Six reported stockpiling the shells. Five of these stored the shells on the processing plant premises and one kept them a short distance away. The average stock of shells was 350 cubic yards. Only one reported treating the stockpiled shells chemically (with hydrated lime) to control odors.

Nine of the respondents reported selling their shells in the year prior to the survey's administration in 2000 at an average price of $11 per cubic yard. Five sold to individuals and four to corporations.

The respondents believed that the primary uses for the shells was to deposit on oyster beds[2] (N=6) and to build road beds (N=4). Seven did not know the primary use.

There was minority support for an oyster shell recycling program (seven of seventeen) in the respondents' region. Respondents expressed a desire to be compensated for their shells and to receive regular retrieval.

Despite the relatively low percentage of the respondents expressing a desire to participate in a processor shell collection plan, the survey results encouraged personnel in the Department of Wildlife and Fisheries Socioeconomic Research and Development Section to consult with processors about the issue. More processors might be willing to cooperate if they were contacted in person and if they had an opportunity to contribute to the design of the program.

[2] Seven respondents had personally planted shells on private leases.

The design of a program would also benefit from the experience of other states. The following chapter presents a brief synopsis of oyster programs in selected states. These will provide some perspective that will be useful in examining proposed programs for cultch collection and oyster ground enhancement in Louisiana.

Chapter 2-4. State Shellfish Programs

The ecological and economic role of oyster reefs in coastal waters has attracted considerable interest from local, state, and federal governments. Every coastal state enforces some type of commercial harvest oversight or control and many enact programs designed to protect or promote shellfish resources.

The necessity of government programs to maintain and conserve public oyster grounds emanates from their nature as "public goods" or "open access" goods. A public good may be defined as any amenity that is readily available to all consumers or participants, whether they have paid for it or not, once the item is provided. Ownership is not assigned to a single individual or entity, but to a larger heterogeneous unit, such as a community, state, or nation.

Public goods, without state intervention, are prone to excessive use and insufficient investment. Individuals have a reduced incentive to practice restraint in consumption. They may not choose to forego current consumption for the sake of future use because somebody else may consume the good that he or she left behind before he or she has a chance to do so. Such an individual likewise has little incentive to invest in a resource if somebody else (who did not pay) may freely step in and remove or consume it.

State intervention may correct the public good problem in numerous ways. The state may restrict access, by issuing limited numbers of permits or licenses, or limit extraction, by setting bag limits or other imposed restrictions. The state may also choose to assign exclusive access to the resource to one individual or entity. This is the concept behind Louisiana's policy of leasing oyster grounds to private individuals. Private leaseholders have an enhanced incentive for conservation, maintenance, and investment on those areas to which they have exclusive legal access.

The state may also choose to act as a direct steward of the public good. The state, in this case, runs a variety of investment, maintenance, and conservation programs. This approach to coping with the public good problem is perhaps the most common form of state intervention in public access shellfish resources.

Government-administered shellfish programs generally center on three aims: water quality, seed planting, and reef enhancement. The design and implementation of these programs vary from state to state, depending upon the characteristics and needs of the local oyster fishery.

Water Quality Programs

The health of oyster resources hinges strongly upon the quality of the water in which they are submerged. Excessive sedimentation, perhaps precipitated by storms or changes in land use patterns, can smother oysters. Pollutants can kill them directly or promote the growth of parasites and predators. Other pollutants can contaminate shellfish, making them unfit for human consumption.

States and localities maintain a variety of programs to inspect the water quality. Washington's "early warning system" (Clifford, 2002), Maryland's Clean Water Action Plan (Venso, *et al*., 2002), and Massachusetts' Shellfish Clean Water Initiative (Somerville, 2002) are examples of state programs designed to monitor and improve shellfish beds environmental conditions.

In Louisiana, the state's Department of Health and Hospital's Molluscan Shellfish Program monitors water quality for contaminants, such as fecal coliform, that pose a danger to consumer health. Shellfish growing areas are analyzed and reclassified four times a year: November through February, March through April, May through August, and September through October. In 2003, 1.2 million acres of shellfish growing areas were classified as "prohibited" (Louisiana Department of Health and Hospitals, 2003).

Oyster Seeding: Stock Enhancement

Several states run oyster-breeding programs or designate areas for the growth and collection of immature oysters. These efforts may consist of the operation of public shellfish grounds or intensive production facilities, like hatchery programs.

Connecticut manages public seed beds, funded by bonds approved by the state legislature. Labor and capital are provided by the shellfish industry (Volk, 2002). Rhode Island transports tons of seed oysters annually to Narrangassett Bay from Long Island Sound and Chesapeake Bay (Rice, Valliere, and Caporelli, 2000; Coen, et al., 2002). A program in Washington State, involving tribes, government agencies, and commercial shellfish farmers, spread Olympia oysters in Puget Sound. Citizens search for quality oyster seed and broodstock in an effort to improve the productivity of the oyster fishery (Peabody, 2002).

Maryland runs a hatchery program costing $500,000 per year. The cost of generating and planting seed oysters is $3.00 to $4.00 per bushel of seed oysters (Judy, 2002). A related program, the Chesapeake Bay Foundation, a cooperative effort between Delaware, Maryland, Virginia, and the federal government, uses hatchery seed from selectively bred stock with a resistance to the parasites, Dermo (*Perkinsus marinus*) and MSX (*Haplosporidium nelsoni*) (Mann and Kingsley-Smith, 2002).

Citizens in Maryland and Virginia maintain community gardens that grow seed oysters in local waters until they are large enough to be planted on public reefs. The reefs constructed from these cultured oysters are currently protected against harvests with the goal of developing a sustainable oyster community in the Chesapeake Bay (Brumbaugh, *et al.*, 2000; Reynolds, 2002).

A similar oyster gardening effort hopes to restore shellfish reefs in New Jersey's and New York's Hudson and Raritan Estuary (Stringer, 2002). In New York, a Suffolk County citizen gardening program, the Southold Project in Aquaculture Training (S.P.A.T.), plants seed oysters, clams, and scallops in local waterways for planting elsewhere in Long Island Sound (Tetrault, 2002; Morgan, Tetrault, and Becker, 2002).

The Louisiana Department of Wildlife and Fisheries manages roughly two million acres of oyster grounds under three designations: public seed grounds, public seed reservations, and public tonging areas (Table 2-7). The designations vary concerning permissible gear use and required harvester licenses, as well as by the authority that created them. Both seed grounds and seed reservations are open to properly licensed residential and commercial oyster harvesters using dredges, scrapers, or tongs. Seed grounds are those public oyster reefs that have been designated by the Louisiana Wildlife and Fisheries Commission, while public seed reservations are those that were created by the Louisiana Legislature.

Public seed grounds and reservations are open during seasons set by the Louisiana Wildlife and Fisheries Commission (generally late fall through early spring.) During the season, oyster harvesters may transfer (or "relay") seed oysters (one to three inches wide)

Table 2-7. Public Oyster Reefs in Louisiana

Seed Grounds		
Name	**Parish**	**Approximate Acreage**
Lake Borgne and Mississippi Sound	St. Bernard	Indeterminate
Primary Seed Grounds (Breton and Chandeleur Sounds)	St. Bernard Plaquemines	Indeterminate
Barataria Bay	Jefferson	1,092
Deep Lake	Terrebonne	239
Lake Felicity	Terrebonne	1,859
Lake Chien	Terrebonne	476
Lake Tambour	Terrebonne	433
Lake Mechant		2,131
Vermilion & Cote Blanche Bays	St. Mary Iberia Vermilion	Indeterminate
Public Seed Reservations		
Bay Gardene	Plaquemines	2,712
Hackberry Bay	Jefferson Lafourche	Indeterminate
Sister Lake (Caillou Lake)	Terrebonne	7,752
Bay Junop	Terrebonne	2,448
Public Tonging Areas		
Calcasieu Lake	Cameron	Indeterminate
Sabine Lake	Cameron	Indeterminate

from public seed grounds to their private leases where the oysters may be harvested upon reaching market size (three inches or larger).

Two public tonging areas in western Louisiana were created by the Louisiana legislature, one in Sabine Lake and one in Lake Calcasieu. Access to these areas is limited to oyster harvesters using tongs.

Cultch Planting Programs

Oyster reefs must periodically be replenished in order to maintain long-term productivity. Many states have active programs to collect recycled oyster shells or other suitable cultch material for deposition in shellfish-producing areas. One common obstacle to these programs is a lack of sufficient quality of shell (MacKenzie, 1989; Breitburg, *et al.*, 2000). This section contains brief synopses of some states' attempts to address this problem.

The state of Connecticut collects shells from shucking houses that process Connecticut oysters. Trucks shipping oysters to processing facilities carry shell back to the coast on the return trip (Volk, 2002).

Massachusetts has no central cultch collection or deposition program. Local governments collect bay scallop shells and surf clam shells for recreational oyster reef development (Hickey, 2002).

The state of New Jersey uses surf clam shells and fly ash as cultch in the Cape May area. The reef enhancement is funded by a per bushel fee assessed on New Jersey oystermen (Babb, 2001).

Maryland obtains approximately 100,000 bushels of shell per year from two sources of cultch: shell from shucking houses and fossil shell dredged from the Chesapeake Bay. Half of this cultch is sent to the state's hatchery program. The state appropriates \$1.6 million to the public fishery and \$2 million to the sanctuary reef program, designated areas protected from harvests to develop a sustainable population of shellfish in the Chesapeake Bay (Judy, 2002).

Virginia spends approximately \$700 thousand per year for oyster reef restoration. In 2001, the state of Virginia and the U.S. Army Corps of Engineers began a \$2.55 million project to build eight one-acre experimental oyster plots and 150 acres of traditional oyster harvesting grounds in Tangier and Pocomoke Sounds near the Maryland border (Harper, 2001). The Virginia Oyster Reef Heritage Program, a cooperative program combining nine Virginia state agencies, five federal agencies, and eight private organizations, plans to build a network of nine oyster reefs near the Rappahannock River. Each site will consist of a central one-acre oyster sanctuary reef surrounded by 25 acres of harvest reef. The projected cost for each site is $384 thousand (Virginia Oyster Reef Heritage Program, 2001).

South Carolina has created an oyster shell recycling program, funded by recreational oyster fishing licenses, to collect shells from final users. Members of the public voluntarily deliver shells to collection points throughout the state while the state collects between 700 and 900 bushels of shells daily from participating restaurants and caterers. After being stored sufficiently long to cure them, the shells are used as cultch in coastal waters. At an annual estimated cost of $100,000, this effort has collected 16,000 bushels of shell in 2003 and has created 50 new reefs for recreational oyster harvesting since its inception in 2002 (Anderson, *et al.*, 2002; Hennessy, 2003).

North Carolina has a multi-faceted oyster reef enhancement program, including shell plants in addition to recruitment and water quality efforts. (The annual costs of North Carolina's oyster restoration program in the late 1990's equaled $700,000.) The state has restored oyster reefs using oyster shell and marine limestone (marl) in West Bay, Pamlico Sound, the Neuse River estuary, and Ocracoke Island (Lenihan and Grobowski, 1998). The Army Corps of Engineers has also constructed 15 acres of intertidal and subtidal reef using marine shell and marl for cultch near Roanoke Sound and Newport River (Birch, Luckenbach and Ross, 2002). Some communities within the state are also attempting post-consumer shell recycling. A community based effort in

Jacksonville, North Carolina, is similar to the South Carolina program that gathers shells through voluntary donations from restaurants and consumers (Dees, 2003).

Processors in Florida must return half of the shell from state-harvested oysters. Most of the processors are concentrated in the Apalachicola area and participate in an extensive cultch collection program. Shells are collected regularly from area processors and stored on land for periodic deposition on public oyster grounds.

Alabama also requires its oyster processors to return a quantity of shell equivalent to half the shell derived from state waters. As an incentive for processors to provide larger quantities of shell, the state offers to pay the cost of shipping if the processors return all the shell from Alabama oysters. (The vast majority of oysters processed in Alabama were harvested in other states. Shells from these oysters originating outside Alabama do not have to be returned to state waters.) The state typically plants 3,500 to 4,000 cubic yards of shell; the largest was 7,000 cubic yards. License fees and tag fees fund the planting and hauling, but not purchasing the shell (Van Hoose, 2001).

Mississippi recently created acres of public oyster reefs, funded in part by federal dollars. The state encourages local processing by a differentiated tag fee system. Oystermen pay 15 cents per sack for oysters sold to Mississippi processors but 50 cents per sack on oysters shipped to processors in other states (Lewis, 2001).

Conclusion

This chapter presents brief descriptions of the oyster reef improvement policies from a selection of states. Each program is peculiar to the needs and nature of the oyster fisheries of the respective states. Louisiana's oyster reef enhancement efforts will be distinguished from these largely due to differences in scale. The state's oyster ground replenishment program must reflect the scope of Louisiana's commercial oyster harvest, which is larger than that of any other state.

A key issue in the construction of an oyster reef enhancement program is the availability of cultch. Louisiana's oyster processing plants may collectively generate large quantities of shells as a by-product of processing shucked oysters, but they are spread throughout the state, as Chapter 3 has demonstrated. Therefore, the Louisiana Department of Wildlife and Fisheries must consider alternative cultch materials, such as concrete and limestone, should a sufficient quantity of oyster shells remain unobtainable.

The following chapter will present three proposed programs for obtaining and depositing cultch. Two examine the collection of oyster shells from processing houses and one examines the use of alternative materials to build or enhance public oyster grounds. This chapter will discuss only the design and cost of these programs, not their funding, a complex and sensitive issue beyond the purview of this analysis.

Chapter 2-5. Examining Cultch Acquisition and Deposition Systems in Louisiana

An essential element of all oyster reef enhancement programs is the selection of an appropriate cultch material. This decision must weigh a variety of factors including weight, size, consistency, durability, and the ability to attract oyster larvae and produce mature oysters. An extensive body of literature identifies the advantages and disadvantages of various forms of cultch, including oyster shell, clam shell, crushed concrete, slate, and limestone (Lunz, 1958; Brodtmann, 1991; Chatry, Dugas, and Laiche, 1986; Haven, *et al.*, 1987; Soniat, Broadhurst, and Haywood, 1991).

The dearth of appropriate materials is often a serious limiting factor in efforts to build, replenish, or improve oyster beds. Certain materials, especially oyster shells, that possess a demonstrated ability to attract and produce oysters are not available in quantities sufficient for oyster reef enhancement projects.

The cost of cultch material is as much of a consideration as its availability. Collecting cultch from its original source to a staging area before deposition may involve expensive transportation, handling, and storage costs. The extent of these costs may limit the size and scope of oyster reef enhancement efforts.

This analysis will examine a variety of cultch acquisition and deposition programs in Louisiana, involving various operation plans and cultch materials. It will present cost estimates and feasibility projections, based on geographical distribution and time-completion requirements.

Three proposed programs will examine the “recycling” (collection) of oyster shells from processing plants that will be deposited on public oyster grounds. The first proposal is an "oyster shell recycling" program operated entirely by Louisiana Department of Wildlife and Fisheries personnel using Department-owned equipment and facilities. The second proposal allots oyster shell collection and deposition duties to separate entities or subcontractors under Department supervision. The third proposal entails a combination of Department resources and subcontractors. Separate entities would transport the processing plants' oyster shells to a stockpiling site, from which they would later be barged and deposited on public oyster grounds by the Department's vessels and employees.

Under the fourth proposal (which is not an "oyster shell recycling" program), the Department would hire a private contractor to acquire and deposit cultch: oyster shell, crushed limestone, or crushed concrete. The contactor would obtain the specified cultch independently from its own sources, inside or outside Louisiana, at its own discretion.

Proposed Program: Department of Wildlife and Fisheries-Operated and -Administered Collection of Oyster Shells

The first proposed program would involve the collection of oyster shell from processing plants by Department employees using Department-owned equipment. A model of this may be seen in the Florida Bureau of Marine Resources' oyster shell recycling program in Apalachicola Bay, the center of the state's commercial oyster industry. Shells are picked up from the processors on a regular basis and loaded onto a dump truck by a front-end loader transported to each processing plant on a trailer towed behind the truck. All of the vehicles involved in the retrieval process are owned by the Bureau of Marine Resources and are operated by Bureau employees.

The shells are transported from the processing plants to a water-accessible location on the Bay where they are stockpiled. When a sufficient quantity of shell has been collected, the shells are loaded onto a Bureau-owned barge and pushed by a Bureau-owned tug boat to the location where they are deposited. The cost of acquiring the vehicles, barge, vessels, and the equipment and facilities to maintain them, according to the program coordinator, was approximately $2,000,000.

It would be difficult to replicate a program that would service all the processing plants in Louisiana with a single facility location due to their geographical dispersion. While one centrally-located facility in Florida can collect a sizable quantity of shell (from 3-4 million pounds of oyster meat) from several processors within a radius of a few miles, one centrally located facility in Louisiana would face logistical challenges in reaching and serving processors in eight parishes separated by hundreds of miles of coast and several hours of highway driving time. To establish a program in Louisiana that can reach all the processing plants in the state, the Department would need to establish multiple shell collection facilities.

The Cost of Establishing a Shell Collection Facility: Initial Investment Costs

The initial investment costs, or fixed costs, of establishing a shell collection facility involves the cost of acquiring the vehicles and equipment needed to collect the shells. As the Department already possesses some of the assets necessary for this operation, the initial investment costs would include only the costs of acquiring the required equipment not currently available for a shell collection program.

Personnel in the Socioeconomics Research and Development Section examined the Department's inventory to identify existing assets that could be used for a shell collection program. This effort identified a tug boat and three barges under the control of the Fur and Refuge Division that could be used to haul shell from a collection site and deposit it on a public oyster reef. These resources have been previously used in similar projects (1997).

The Department would need to acquire several pieces of equipment for regular use in a shell collection project: two dump trucks with a capacity of at least ten cubic yards, two tractors with a front-end loader and back hoe, and two trailers to transport the tractor. (Multiple pieces of equipment are deemed necessary to assure continuous and efficient operation). Socioeconomic Research and Development Section personnel obtained cost estimates for trucks, tractors, and trailers (Table 2-8) by contacting internet sales sources. These estimates are for new vehicles and equipment with the stated capacity. The longevity of the equipment is assumed to be ten years.

This analysis assumes that the vehicles and equipment may be stored at local Departmental facilities at no additional cost to the Department. The Department would, however, incur additional costs in protecting the stockpile of shell against theft, especially if the shell is stored separately from existing Departmental facilities. Security costs consist of the expense of a fence to surround the stockpile of shell. The cost estimate in Table 2-8 assumes that 700 feet of six-foot tall fencing is sufficient for this purpose.

Table 2-8. The Initial Investment Cost of a Shell Collection Facility in Louisiana

Item	**Description**	**Purchase Cost**	**Quantity**	**Total Cost**
Vehicles & Equipment				
Pintle Hitch Trailer (10 Ton)	24 ft.	$ 8,000	2	$ 16,000
JD Tractor (with front-end loader & back hoe)	42 – 62 hp	$ 45,000	2	$ 90,000
Dump Truck	4 x 6	$ 55,000	2	$110,000
Total Vehicle & Equipment Cost				$216,000
Security Cost				
Fence ($15.06 per foot)	700 feet	$ 10,542	1	$ 10,542
Total Security Cost				$ 10,542
Total Initial Investment Cost				$226,542

A Hypothetical Pilot Program for Oyster Shell Collection

Because of the geographical distribution of Louisiana's oyster processing plants, a statewide program of this nature would require multiple shell collection facilities at an estimated investment cost of over $225 thousand each. At such a cost, the Department should examine one shell collection facility as a pilot program at a local or regional level to test the practical aspects of an oyster shell recycling program before undertaking the expense of multiple facilities.

To set up a hypothetical pilot program, the Department had to identify a location in which a large quantity of shell is available in a small area. To this end, the Department examined the volume of oyster processing at the parish level using data from the N.M.F.S. Seafood Processors Survey.

Terrebonne Parish in south-central Louisiana is the parish with the largest volume of output for fresh shucked oysters, 1.348 million pounds of oyster meat in 2000. There are several processors in the parish seat, Houma, and its neighbor, Dulac. Roads in the parish are adequate for the ground transportation vehicles needed to retrieve and deliver the shell. There are numerous waterways capable of accommodating the barge needed to carry the shell from the staging area to the public grounds.

Furthermore, within Terrebonne parish, there are five public seed grounds (Deep Lake, Lake Felicity, Lake Chien, Lake Tambour, and Lake Mechant totaling 6,230 acres) and two seed reservations (Sister Lake and Bay Junop totaling 10,200 acres). The commercial oyster harvest from these public oyster grounds in 2001 was 467,865 pounds of meat.

Estimating the Volume of Available Oyster Shell in Terrebonne Parish

To gauge the availability of oyster shells from Terrebonne Parish processing plants, four employees from the Socioeconomics Research and Development Section and the Marine Fisheries Division of the Louisiana Department of Wildlife and Fisheries met with the owners of six processing plants[3] at the Department's office in Bourg, Louisiana on June 25, 2002. These processors supported the concept of collecting oyster shells for public reef enhancement and agreed in principal to offer one-half[4] of their shells at the going market rate.

In 2000, N.M.F.S. data indicate that Terrebonne Parish processing plants produced 1.384 million pounds of oyster meat. Using the conversion rate of 93.57 pounds per oyster meat per cubic yard of shell, these processors generated an estimated 14,791 cubic yards[5] of shell. One half of this quantity, according to the processors who expressed a willingness to participate, would be available for the oyster shell reef enhancement program: 7,396 cubic yards of shell.

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[3] The processors in attendance were Buddy's Seafood, D & T Seafood, Gautier Enterprises, Motivatit Seafood, PBS Inc., and Wilson's Oysters, Inc.

[4] The processors wish to retain a portion of their shells for established customers.

[5] (1,384,000/93.57) = 14,791 cubic yards of shell.

The current market price of a cubic yard of oyster shells is $17, according to the Pontchartrain Materials Corporation of New Orleans, Louisiana. The total cost of purchasing this quantity of shell from the processors would thus be $125,732. It is probable, however, that a massive purchase of shell, as would an increase in the demand for any good, will push the price of shell above the current market price.

Identifying a Stockpiling Site in Terrebonne Parish

Having estimated the cost of acquiring the oyster shells from the processors, the Department then wanted to determine a suitable stockpiling site, near the processing plants and accessible to roads and navigable waterways. Two employees from the Socioeconomics Research and Development Section and the Marine Fisheries Division of the Louisiana Department of Wildlife and Fisheries met with officials[6] of the Terrebonne Parish government in Houma, Louisiana on March 27, 2003. These officials offered a choice of two sites that may be used by the Department to store shells.

One of the sites was deemed acceptable after an inspection of both potential sites on May 8, 2003. Located off Falgout Canal Road (Highway 10) at the Pontoon Bridge over the eponymous canal, it is accessible to trucks for delivery and to barges for retrieval. The site may be surrounded by a fence for security. The bridge tender of the adjacent bridge is available for continuous observation.

The cost of storage and stockpiling is minimal. Because the Terrebonne Parish government is willing to make land available at no cost, the expense of stockpiling is confined to the cost of erecting the chain-link fence to safeguard the stockpiled shell.

[6] In attendance were the Parish Manager, the Operations Manager of Public Works, and Cultural Resources and Economic Development director.

Estimating the Cost of Transporting Shells from Processing Plants to the Stockpiling Site

The costs of retrieving the shells from the oyster processing plants and transporting them to the Falgout Canal stockpiling site consists of the operating expenses for office equipment and supplies, labor, fuel, and vehicle and equipment repair and maintenance (Table 2-9).

Table 2-9. Estimated Operating Cost for a Department-Run Oyster Shell Collection Facility in Terrebonne Parish, Louisiana

Labor Costs						
Position	**Annual Wage or Salary**			**Qty.**	**Operating Cost**	
Supervisor	$29,307			1	$29,307	
Operator	$20,339			2	$40,678	
	Total Wages and Salaries					$69,985
		Benefits (22 percent of wages and salaries)			$15,397	
	Total Wages, Salaries, and Benefits					$85,382
		Indirect Costs (50.2 percent of total wages, salaries, & benefits)			$42,862	
Total Labor Cost						$128,244
Office Equipment and Supplies Costs						
Item					**Operating Cost**	
Computer					$5,000	
Supplies					$3,000	
Total Office Equipment and Supplies Costs						$8,000
Vehicle and Equipment Costs						
Item	**Direct Costs* per Hour**	**Hours per Year**	**Annual Operating Cost**	**Qty.**	**Operating Cost**	
Trailer	$ 1.61	1,200	$ 1,932	2	$ 3,864	
Tractor	$ 5.42	600	$ 3,252	2	$ 6,504	
Dump Truck	$11.12	1,200	$13,344	2	$26,688	
Total Vehicle and Equipment Costs						$37,056
Total Operating Expenses						$173,300
* Direct Costs include fuel, repair, and maintenance costs.						

Operating a shell collection plan would require hiring three employees: two operators and a supervisor. The wages and salaries of these employees were based on the Louisiana Civil Service Pay Grid for personnel in the appropriate category. Benefits are calculated as 22 percent of the employees' wages or salaries. Indirect costs, including such items as administration, accounting, accounts payable, insurance, and utilities, are 50.2 percent of total wages, salaries, and benefits.

Office equipment would consist mainly of computing and communication devices with an estimated operating cost of $5,000. Office supplies are projected to cost $3,000.

The vehicle and equipment costs are based on hourly cost rates derived from Louisiana Agricultural Center cost budgets (Paxton, 2003). The dump truck and trailer are estimated to operate 1,200 hours per year (5 hours per day, 5 days per week, forty-eight weeks per year). Because they will be used only at the processing plants and not in transit, the tractors will be operated for fewer hours per year (600 hours) than the dump trucks and trailers.

The total costs of operating a state-operated facility to transport oyster shells from the Terrebonne Parish processors to the Falgout Canal stockpiling site are $173,300 per year. Based on an estimated quantity of 7,396 cubic yards of shell, the cost per cubic yard is $23.43.

Estimating the Cost of Transporting to and Depositing Shell on Oyster Grounds

The final stage in the oyster shell reef enhancement project is the ferrying of the stockpiled shells to a public reef for deposition. The Louisiana Department of Wildlife and Fisheries currently possesses the capacity to transport oyster shell from the Falgout Canal stockpiling site to nearby public oyster grounds. The Fur and Refuge Division maintains an array of marine vessels and equipment: a tug boat, crane and clam bucket, and three barges with 160-ton capacity each. Several Fur and Refuge Division employees have experience in past cultch deposition projects. Vessels, equipment, and staff are stationed at the Louisiana Department of Wildlife and Fisheries' Marsh Island Wildlife Refuge, a three-day journey from Terrebonne Parish.

The Fur and Refuge Division expresses its labor and fuel costs in "per day" units. The total cost of oyster shell collection and deposition depends upon the time needed to complete the project. Project completion estimates assume that three barges may be loaded and moved by one tug boat simultaneously in a "three-barge chain."

The project completion time must include the six-day round trip between the Marsh Island Wildlife Refuge and the Falgout Canal oyster shell stockpiling site. It must also consider the time needed to load and unload each three-barge chain plus transportation between the stockpiling site and public oyster grounds.

Loading and unloading a three-barge chain, according to Fur and Refuge Division estimates, will take the equivalent of one day. This is split evenly between loading at the Falgout Canal stockpiling site (one-half day) and unloading on the public oyster reefs (also one-half day).

The final cost of depositing oyster shells on a particular public reef can vary significantly depending on its location. As seen in Chapter 2-4, the Department maintains 15 public oyster reefs in 9 parishes. The cost of depositing cultch on a specific public oyster reef depends upon the distance between it and the Falgout Canal stockpiling site. Delivering cultch to reefs in Terrebonne Parish will entail less time and travel and lower costs than reaching more distant oyster grounds.

This research will first estimate the cost of transporting and depositing oyster shells from the Falgout Canal stockpiling site to public oyster grounds within Terrebonne parish. The cost estimates presented will be based on deposition on the Sister Lake Seed Reservation. The Sister Lake site will serve as a proxy for the other public oyster reefs in Terrebonne Parish (Deep Lake, Lake Felicity, Lake Chien, Lake Tambour, Lake Mechant, and Bay Junop.)

For each three-barge chain, the round-trip transportation time from the Falgout Canal stockpiling site to the nearby Sister Lake Public Seed Reservation is one day. All totaled, loading, unloading, and transporting each three-barge chain will take two days (one-half day loading, one-half day unloading, and one day round-trip between the stockpiling site and the Sister Lake Seed Reservation).

Assuming each 160-ton barge can hold approximately 300 cubic yards of oyster shells, a three-barge chain can move 900 cubic yards of shell at one time. The estimated quantity of oyster shell expected from the Terrebonne Parish processing plants (7,396 cubic yards) will require eight (8) three-barge chains and sixteen (16) days for loading, unloading, and transportation.

Water transportation is often delayed by weather and other events. The project completion time will include six days for negative contingencies, five days for inclement weather (the average number of days of rain per month) plus one day for other circumstances.

The total project completion time for deposition at the Sister Lake Seed Reservation is 28 days. This includes, in summary, sixteen days for loading, transportation, and unloading, six days for negative contingencies, and six days for the round-trip voyage between the Marsh Island Wildlife Refuge docking site and Terrebonne Parish.

Fuel costs (Table 2-10) are based on an estimate of 250 gallons of diesel fuel per day of operation. Based on an average price per gallon of $1.559 (the statewide average on January 15, 2004 reported by the American Automobile Association), total fuel costs for the 28-day project are $10,913.

Operating the vessels and equipment requires three employees, a deckhand (pay scale GS-11), a heavy equipment operator (pay scale GS-14), and a marine operator [boat captain] (pay scale GS-15). Wages and salaries of employees were estimated to be $390.64 per day. Adding 22 percent for benefits, total wages, salaries, and benefits equals $476.58. Including indirect costs of 50.2 percent of total wages, salaries, and benefits, total labor costs per day are $715.82. Total labor costs for the 28-day project are $20,043.

Maintenance costs are estimated by the Fur and Refuge Division as three percent of labor and fuel costs or $929.

Total operating cost of transporting and depositing shell on the Sister Lake Seed Reservation is $31,885. Based on an expected quantity of 7,396 cubic yards, the transportation and deposition cost per cubic yard is $4.31.

The cost of transporting oyster shells from the Falgout Canal stockpiling site to more distant oyster grounds will rise with the increase in travel time. This research will present cost estimates for deposition in Barataria Bay (a 2-day trip from Terrebonne Parish) and Vermilion Bay (a 3-day trip from Terrebonne Parish).

Table 2-10. Operating Costs for Department-Run Transportation and Deposition of Cultch Material, from Falgout Canal to Sister Lake Seed Reservation

Labor Costs					
Position			**Cost Per Day**		**Total Project Cost**
Deck Hand			$110.48		
Heavy Equipment Operator			$135.36		
Marine Operator			$144.80		
	Total Wages and Salaries			$390.64	$10,938
		Benefits	$ 85.94		
	Total Wage, Salary, and Benefits			$476.58	$13,344
		Indirect Costs	$239.24		
Total Labor Costs				$715.82	$20,043
Fuel Cost					
Item	**Consumption Rate**	**Unit Price**	**Cost per Day**		**Total Project Cost**
Diesel Fuel	250 gallons/day	$1.559/gallon		$389.75	$10,913
Total Labor and Fuel Costs					$30,956
Maintenance Cost (3 percent of total labor and fuel costs)					$ 929
Total Operating Costs					$31,885

The round-trip between the Falgout Canal stockpiling site and Barataria Bay is approximately 4 days. Including time for loading and unloading, the estimated time to load, transport, and unload each three-barge train is 5 days. The total loading, transporting, and unloading time estimate for 8 three-barge chains is 40 days, the equivalent of two months of business days. Adding 6 days for the round trip between the Marsh Island docking site and the stockpiling site and 11 days for inclement weather and other negative contingencies, the total project completion time for a Barataria Bay deposition is 57 days.

Total labor and fuel costs (Table 2-10A), based on the previously established cost of labor ($715.82 per day) and fuel ($389.75 per day), are $63,017. Estimated maintenance costs (3 percent of total labor and fuel costs) are $1,891. Total cost of the

Table 2-10A. Operating Costs for Department-Run Transportation and Deposition of Cultch Material, from Falgout Canal to Barataria Bay

Labor Costs				
			Cost Per Day	**Total Project Cost**
Total Labor Costs			$715.82	$40,802
Fuel Cost				
Item	**Consumption Rate**	**Unit Price**	**Cost per Day**	**Total Project Cost**
Diesel Fuel	250 gallons/day	$1.559/gallon	$389.75	$22,216
Total Labor and Fuel Costs				$63,017
Maintenance Cost				$ 1,891
Total Operating Costs				$64,908

transporting to and depositing shell in Barataria Bay are estimated as $64,908. Based on an expected quantity of 7,396 cubic yards, the transportation and deposition cost per cubic yard is estimated to be $8.78.

Transporting oyster shells from the Falgout Canal stockpiling site to Vermilion Bay for deposition on public oyster grounds will take an estimated 7 days per three-barge chain. The time estimate for loading, unloading, and transporting 8 three-barge chains is 56 days, the equivalent of nearly 3 months of business days. Adding 6 days for the round-trip between the Marsh Island docking site and the stockpiling site and 14 days for inclement weather and other contingencies, the total project completion time for a Vermilion Bay deposition is 76 days.

Total labor and fuel costs for the 76-day project (Table 2-10B) are estimated to be $84,023. Including estimated maintenance costs ($2,521), the total costs for transporting shell from the Falgout Canal stockpiling site and depositing them on public oyster grounds in Vermilion Bay are estimated to be $86,544. The cost per cubic yard is $11.70, assuming a quantity of 7,396 cubic yards of oyster shell.

Table 2-10B. Operating Costs for Department-Run Transportation and Deposition of Cultch Material, from Falgout Canal to Vermilion Bay

Labor Costs					
			Cost Per Day		**Total Project Cost**
Total Labor Costs				$715.82	$54,402
Fuel Cost					
Item	**Consumption Rate**	**Unit Price**	**Cost per Day**		**Total Project Cost**
Diesel Fuel	250 gallons/day	$1.559/gallon	$389.75		$29,621
Total Labor and Fuel Costs					$84,023
Maintenance Cost					$ 2,521
Total Operating Costs					$86,544

The length of time required for transporting oyster shell from the Falgout Canal stockpiling site to the various public oyster grounds will have an effect on management decisions. Oyster resource managers prefer to deposit cultch in May or October when oyster recruitment is at its heaviest. A cultch deposition effort that took one month or less would be optimal, putting in place all of the material in time for the most productive oyster recruitment period. Cultch deposition efforts that two to three months for completion would make it impossible to deposit all of the cultch during the height of oyster recruitment. Some of the cultch would be deposited after the peak recruitment period.

The estimated completion time for the Sister Lake project (28 days) is consistent with the manager's preferences to deposit cultch in the span of one month or less. The entire estimated quantity (7,396 cubic yards) of oyster shell stockpiled at the Falgout Canal site may be transported and deposited in Sister Lake during one of the peak months of May or October.

It would take more than one month to transport the entire estimated quantity of oyster shell (7,396 cubic yards) to more distant locations, Barataria Bay (57 days) and Vermilion Bay (76 days). For these sites, oyster reef managers may choose to place on the public reefs a smaller quantity of shell that could be deposited within the selected one-month timeframe (May or October). Another option is to deposit the entire quantity at once, beginning in May or late April and extending into early summer or hire someone to assist in the deposition of cultch material.

Estimating the Total Annual Cost of a Department-Run Oyster Shell Collection Program

The total annual cost of an oyster shell collection program run by the Department of Wildlife and Fisheries is the sum of operating costs and the pro-rated investment costs. Operating costs included in Tables 2-11, 2-11A, and 2-11B are the total operating costs for collecting the shells from processors (Table 2-9) and transporting the shells from the stockpiling site to the public oyster grounds in Sister Lake (Table 2-10), Barataria Bay (Table 2-10A), or Vermilion Bay (Table 2-10B).

Initial investment costs are pro-rated to an annual basis by assuming a 10-year useful life for the vehicles and equipment (Table 2-8). The combined salvage value of the dump truck, trailer, and tractor is estimated to be \$21,600 (10 percent of the original purchase price, \$216,000). The salvage value of the fence is assumed to be zero. Annual investment costs are the quotient of the total purchase cost minus salvage value divided by the assets' useful life, 10 years:

$$\text{Annual Investment Cost} = \frac{(\$216{,}000 - \$21{,}600)}{10} = \frac{(\$194{,}400)}{10} = \$19{,}440.$$

Table 2-11. Total Costs for a Department-Run Oyster Shell Collection and Deposition Program, from Falgout Canal to Sister Lake

Investment Costs		**Annual Cost**	
Annual Investment Costs*			$19,440
Operating Costs			
Item		**Operating Expenses**	
Purchase of Oyster Shells from Processors		$125,732	
Transporting from Processors to Stockpiling Site		$190,629	
Transporting from Stockpiling Site to Oyster Grounds		$ 31,885	
Total Operating Costs			$348,246
Total Cost			$367,686
* Annual Investment Costs are based on 10-Year Useful Life and 10% Salvage Value)			

The total estimated cost for collection and deposition in Sister Lake (Table 2-11) exceeds $367 thousand per year. Assuming a quantity of 7,396 cubic yards of oyster shell, the total cost per cubic yard would be $49.71

Total estimated costs rise for more distant sites because of the higher cost of transportation from the stockpiling site to the designated oyster grounds. Total costs for Barataria Bay (Table 2-11A) rise to over $400 thousand per year ($54.18 per cubic yard based on an estimate quantity of 7,396 cubic yards). The total estimated costs for depositing the collected shells in Vermilion Bay (Table 2-11B) are $422,345 or $57.10 per cubic yard assuming a total of 7,396 cubic yards.

Table 2-11A. Total Costs for a Department-Run Oyster Shell Collection and Deposition Program, from Falgout Canal to Barataria Bay

Investment Costs		**Annual Cost**	
Annual Investment Costs*			$19,440
Operating Costs			
Item		**Operating Expenses**	
Purchase of Oyster Shells from Processors		$125,732	
Transporting from Processors to Stockpiling Site		$190,629	
Transporting from Stockpiling Site to Oyster Grounds		$ 64,908	
Total Operating Costs			$381,269
Total Cost			$400,709
* Annual Investment Costs are based on 10-Year Useful Life and 10% Salvage Value)			

Table 2-11B. Total Costs for a Department-Run Oyster Shell Collection and Deposition Program, from Falgout Canal to Vermilion Bay

Investment Costs		**Annual Cost**	
Annual Investment Costs*			$19,440
Operating Costs			
Item		**Operating Expenses**	
Purchase of Oyster Shells from Processors		$125,732	
Transporting from Processors to Stockpiling Site		$190,629	
Transporting from Stockpiling Site to Oyster Grounds		$ 86,544	
Total Operating Costs			$402,905
Total Cost			$422,345
* Annual Investment Costs are based on 10-Year Useful Life and 10% Salvage Value)			

Proposed Program: Department of Wildlife and Fisheries-Administered Program Operated by Subcontractors

The second alternative for collecting oyster shell from processing plants would remove the necessity of acquiring equipment and hiring employees. Under this scheme, the Department would hire separate entities (business or local government) to retrieve shells, to stockpile them, and to transport and deposit them on public oyster reefs. Each of these functions could be performed separately by a different business or organization.

Estimating the Initial Invest Costs

Hiring subcontractors would spare the Department the necessity of purchasing trucks, trailers, and tractors. The initial investment costs would consist only of the cost of a security fence at the Falgout Canal stockpiling site. As previously cited in Table 2-8, the cost of a 700-foot fence is estimated as $10,542. Assuming zero salvage value and a ten-year useful life, the annual investment costs would thus be $1,054.

Estimating the Cost of Transporting Shells from Processing Plants to the Stockpiling Site

To determine the cost of ground transportation, carrying the shell from the processing plants to the stockpiling site, the Louisiana Department of Wildlife and

Fisheries Socioeconomic Research and Development Section contacted the Terrebonne Parish Public Works Operations Manager. He was able to provide two estimates for retrieving and transporting the processors' shells to the Falgout Canal storage site. The cost to hire Parish employees and facilities was $33 per cubic yard. The cost of a private subcontractor in the area was $30 per cubic yard.

Since there is no perceivable difference in quality, the Department would select the low bidder. The total cost of ground transportation of 7,396 cubic yard of shell from processing plants to the stockpiling site is $221,880.

Estimating the Cost of Transporting to and Depositing Shell on Oyster Grounds

The final stage in the oyster shell reef enhancement project is the ferrying of the stockpiled shells to a public reef for deposition. Personnel from the Socioeconomic Research and Development Section contacted four area firms with the minimum capacity to perform the service.[7] The Department asked the firms for estimates of the cost of loading at least 6,000 cubic yards of oyster shell from the Falgout Canal stockpiling site and transporting it to Sister Lake, a public oyster ground in Terrebonne Parish identified by the Marine Fisheries Division as a potential site for reef enhancement.

One firm provided an estimate of $30 per cubic yard; another, an estimate of $11 per cubic yard for delivery and deposition in Sister Lake. (Neither of the other firms provided an estimate.) Both of the firms offering estimates have crane and bucket systems, not the high-pressure hose apparatus preferred by the Department's oyster program managers.

[7] The Department obtained the names and telephone numbers of firms with the required capacity from the Terrebonne Parish Public Works Operations Manager.

Because there is no perceivable difference in the quality of service offered by these firms, the Department would prefer the low estimate. The firm offering the low estimate for deposition in Sister Lake was also able to provide estimates for three other locations: $14 per cubic yard for the Barataria Basin, $16 per cubic yard for Vermilion Bay, and $22 per cubic yard for Calcasieu Lake.

The cost of cultch deposition of 7,396 cubic yards of oyster shells in Sister Lake is $81,396. The cost is $103,544 to deposit cultch material in the Barataria Basin, $118,336 in Vermilion Bay; and $162,712 in Calcasieu Lake.

Estimating the Total Cost of Acquiring, Transporting, and Depositing Cultch

The cost of acquiring 7,396 cubic yards of oyster shells from Terrebonne Parish processing plants, transporting them to the Falgout Canal stockpiling site, and depositing them in Sister Lake using private subcontractors is $428,968 ($58 per cubic yard) (Table 2-12). Including the pro-rated cost of a security fence, total estimated costs of the proposed oyster shell recycling program with deposition in Sister Lake are $430,022 ($58.14 per cubic yard).

The costs rise for locations outside Sister Lake ranges because of increased transportation costs. The total costs of the proposed oyster shell recycling program, including the pro-rated cost of a security fence, with an estimated quantity of 7,396 cubic yards, range from $452,210 ($61.14 per cubic yard) in the Barataria Basin (Table 2-12A) to $467,002 ($63.14 per cubic yard) in Vermilion Bay (Table 2-12B) and $511,378 ($69.14 per cubic yard) in Calcasieu Lake (Table 2-12C).

Table 2-12. Total Costs for an Oyster Shell Collection and Deposition Program Operated by Subcontractors, Falgout Canal to Sister Lake

Investment Costs	**Annual Cost**	
Annual Investment Costs*		$1,054
Operating Costs		
Item	**Operating Expenses**	
Purchase of Oyster Shells from Processors	$125,732	
Transporting from Processors to Stockpiling Site	$221,880	
Transporting from Stockpiling Site to Oyster Grounds	$ 81,356	
Cost of Acquisition, Stockpiling, and Deposition		$428,968
Total Cost		$ 430,022
* Annual Investment Costs are based on the purchasing price of a security fence with a 10-Year Useful and Zero Salvage Value.		

Table 2-12A. Total Costs for an Oyster Shell Collection and Deposition Program Operated by Subcontractors, Falgout Canal to Barataria Basin

Investment Costs	**Annual Cost**	
Annual Investment Costs*		$ 1,054
Operating Costs		
Item	**Operating Expenses**	
Purchase of Oyster Shells from Processors	$125,732	
Transporting from Processors to Stockpiling Site	$221,880	
Transporting from Stockpiling Site to Oyster Grounds	$103,544	
Cost of Acquisition, Stockpiling, and Deposition		$451,156
Total Cost		$ 452,210

Table 2-12B. Total Costs for an Oyster Shell Collection and Deposition Program Operated by Subcontractors, Falgout Canal to Vermilion Bay

Investment Costs	**Annual Cost**	
Annual Investment Costs*		$ 1,054
Operating Costs		
Item	**Operating Expenses**	
Purchase of Oyster Shells from Processors	$125,732	
Transporting from Processors to Stockpiling Site	$221,880	
Transporting from Stockpiling Site to Oyster Grounds	$118,336	
Cost of Acquisition, Stockpiling, and Deposition		$465,948
Total Cost		$467,002
* Annual Investment Costs are based on the purchasing price of a security fence with a 10-Year Useful and Zero Salvage Value.		

Table 2-12C. Total Costs for an Oyster Shell Collection and Deposition Program Operated by Subcontractors, Falgout Canal to Calcasieu Lake

Investment Costs	**Annual Cost**	
Annual Investment Costs*		$1,054
Operating Costs		
Item	**Operating Expenses**	
Purchase of Oyster Shells from Processors	$125,732	
Transporting from Processors to Stockpiling Site	$221,880	
Transporting from Stockpiling Site to Oyster Grounds	$162,712	
Cost of Acquisition, Stockpiling, and Deposition		$510,324
Total Cost		$511,378
* Annual Investment Costs are based on the purchasing price of a security fence with a 10-Year Useful and Zero Salvage Value.		

Proposed Program: Combined Department and Subcontractor Operation

Under the third proposed program, a separate entity (a Terrebonne Parish subcontractor) would transport oyster shells from processing plants to the Falgout Canal stockpiling site under the Department's direction. From there, the Department would deposit them on public oyster grounds. This would allow the Department to exploit its low-cost advantage in marine transportation and deposition while avoiding the initial investment cost of a shell collection facility ($226,542). The Department may wish to avoid such costs in establishing a test pilot program which might last only a few years.

As with the Department-administered program operated by subcontractors, the initial investment costs would consist of only the cost of a security fence ($10,542). This costs will be converted into an annual investment cost ($1,054) assuming zero salvage value and a ten-year useful life.

The following tables show the total cost of a program in which a subcontractor shell collects shells from processors and the Department deposits them on oyster grounds in Sister Lake (Table 2-13), Barataria Bay (Table 2-13A), and Vermilion Bay (Table 2-

13B). For each of these sites, the costs of purchasing the oyster shell ($17 per cubic yard) and paying a local firm for ground transportation ($30 per cubic yard) are the same but the cost to the Department of transporting a cubic yard of shell for deposition varies from $4.31 in Sister Lake to $8.78 in Barataria Bay to $11.70 in Vermilion Bay. Consequently, the estimated total cost, including the cost of the security fence, ranges from $380,551 in Sister Lake ($51.45 per cubic yard) to $413,574 in Barataria Bay ($55.92 per cubic yard) to $435,210 in Vermilion Bay ($58.84 per cubic yard).

Table 2-13. Total Costs for a Combined Department and Subcontractor-Operated Program: Oyster Shell Collection (by Subcontractor) and Deposition (by the Department), Falgout Canal to Sister Lake

Investment Costs	**Annual Cost**	
Annual Investment Costs*		$1,054
Operating Costs		
Item	**Operating Expenses**	
Purchase of Oyster Shells from Processors	$125,732	
Transporting from Processors to Stockpiling Site	$221,880	
Transporting from Stockpiling Site to Oyster Grounds	$ 31,885	
Cost of Acquisition, Stockpiling, and Deposition		$379,497
Total Cost		$380,551

Table 2-13A. Total Costs for a Combined Department and Subcontractor-Operated Program: Oyster Shell Collection (by Subcontractor) and Deposition (by the Department), Falgout Canal to Barataria Bay

Investment Costs	**Annual Cost**	
Annual Investment Costs*		$1,054
Operating Costs		
Item	**Operating Expenses**	
Purchase of Oyster Shells from Processors	$125,732	
Transporting from Processors to Stockpiling Site	$221,880	
Transporting from Stockpiling Site to Oyster Grounds	$ 64,908	
Cost of Acquisition, Stockpiling, and Deposition		$412,520
Total Cost		$413,574

Table 2-13B. Total Costs for a Combined Department and Subcontractor-Operated Program: Oyster Shell Collection (by Subcontractor) and Deposition (by the Department), Falgout Canal to Vermilion Bay

Investment Costs	**Annual Cost**	
Annual Investment Costs*		$1,054
Operating Costs		
Item	**Operating Expenses**	
Purchase of Oyster Shells from Processors	$125,732	
Transporting from Processors to Stockpiling Site	$221,880	
Transporting from Stockpiling Site to Oyster Grounds	$ 86,544	
Cost of Acquisition, Stockpiling, and Deposition		$434,156
Total Cost		$435,210

Proposed Program: Private Contractor Independent Acquisition and Deposition of Cultch Material

The fourth proposed program involves the Department's hiring private contractors to locate, purchase, transport, and deposit cultch. The Department would have no responsibility for operations management and would not have to locate cultch or coordinate its collection.

Also, under this alternative, the Department would have a choice of materials to use as cultch: oyster shells, limestone, and crushed concrete. Because limestone and concrete are widely available, using these materials alleviates the problems associated with the limited supply of shell.

Personnel in the Louisiana Department of Wildlife and Fisheries Socioeconomics Research and Development Section contacted three firms capable of depositing various cultch materials at locations throughout the state. One of these firms is based in Baton Rouge, one in New Orleans, and one in Houma.[8]

[8] The firm in Houma also provided estimates for the Terrebonne processor oyster shell project.

Of these firms, one provided consistently low estimates for the delivery and deposition of a variety of cultch materials. This firm also possesses the high-pressure hose apparatus that the Louisiana Department of Wildlife and Fisheries Marine Fisheries Division has used successfully in previous cultch deposition activities. This firm provided the following prices of materials before delivery: $17 per cubic yard for oyster shells; $18 per cubic yard for crushed concrete; and $21 per cubic yard for crushed limestone.

The total costs of acquisition, delivery, and deposition of a cubic yard depend upon location and the type of cultch material (Table 2-14). Because using a private contractor spares the Department the effort and expense of coordinating a complicated collection program, this cost estimate does not include additional administrative costs or indirect costs.

Oyster shell is the least expensive form of cultch for every location that this firm can access. The low cost and the attractiveness of using a natural material for reef enhancement make oyster shell the most appealing alternative material. The firm, however, would not assure the Department that it could attain a sufficient quantity of shell for large cultch plantings in a short period of time (one year). The Department may have to accept a mixture of materials: attaining as large a quantity of oyster shell as possible and supplementing it with crushed concrete or limestone as necessary.

Table 2-14. Cost for Acquisition, Delivery and Deposition of a Cubic Yard of Selected Materials in Four Locations in Louisiana from Firm with Lowest Estimated Cost, 2003

Location	Crushed Concrete	Limestone	Oyster Shell
Breton Sound	$38.71	$39.71	$30.71
Barataria Basin	$45 - $50	$46 - $51	$36 - $41
Sister Lake	$45 - $50	$46 - $51	$36 - $41
Vermilion Bay	$50 - $56	$51 - $57	$41 - $47

Cost Comparisons among Proposed Programs

Table 2-15 presents estimates of the cost of acquiring and planting a cubic yard of cultch material in selected locations under the various proposed programs outlined in this chapter. Cost estimates are not available for all locations under each program. One contractor did not provide an estimate for Breton Sound; the other provided none for Calcasieu Lake. Cost estimates for the two proposed programs involving the deposition of oyster shells in Calcasieu Lake and Breton Sound by vessels owned by the Department are not included in this table because they are located are too far from the oyster shell stockpiling site to be reached in a timely manner. Thus only one cost estimate for these two locations is provided.

Hiring a firm to acquire cultch independently and deposit it on public oyster grounds ("Deposition by a Private Contractor") has the lowest cost per cubic yard among the proposed programs. This firm can plant a variety of materials (oyster shell, crushed concrete, and crushed limestone) in locations across the state using the high pressure hose technology that is favored by Department's shellfish resource managers.

The cost of hiring the private contractor to plant a cubic yard of oyster shell on each of the designated public grounds is considerably less expensive than that of the Department-run shell collection program; however, in the likely event that the firm is unable to acquire an adequate quantity of oyster shell, the cost differential may be irrelevant.

The cost of the oyster shell collection program operated by the Department is competitive with the cost of hiring a firm to acquire and deposit crushed concrete and limestone in Sister Lake. The cost per cubic yard of oyster shells under the Department-

Table 2-15. Comparing Total Costs per Cubic Yard under Described Programs

Program	Cultch	Sister Lake	Barataria Basin	Vermilion Bay	Calcasieu Lake	Breton Sound
Shell Collection Program Run by the Department	Oyster Shell	$49.71	$54.18	$69.14	*	*
Shell Collection Program Run by Subcontractors	Oyster Shell	$58.14	$61.14	$63.14	$69.14	**
Combined Program: Shell Collection (by Subcontractor) and Deposition (by Department)	Oyster Shell	$51.45	$55.92	$58.84	*	*
Deposition by a Private Contractor	Oyster Shell	$36 - $41	$36 - $41	$41 - $47	***	$30.71
Deposition by a Private Contractor	Crushed Concrete	$45 - $50	$45 - $50	$50 - $56	***	$38.71
Deposition by a Private Contractor	Crushed Limestone	$46 - $51	$46 - $51	$51 - $57	***	$39.71
* Due to time constraints, Department-owned resources can not feasibly deposit cultch in areas outside Terrebonne Parish.						
** Cost estimates for Breton Sound were not available.						
*** Cost estimates for Calcasieu Lake are not available.						

run collection program ($49.74) is roughly equal to the upper end of the cost range offered by the private contractor for crushed concrete ($50 per cubic yard) and crushed limestone ($51 per cubic yard). The difference between the cost of a cubic yard of oyster shell under the Department-run collection program and the lower end of the cost range for a cubic yard of crushed concrete or limestone from the private contractor is approximately $5 for Sister Lake, $10 for the Barataria Basin, and $6 for Vermilion Bay.

The proposed program involving the combined efforts of a subcontractor for transportation of shell between processors and the stockpiling site and the Department for transportation from the stockpiling site to the designated public oyster grounds is more expensive than establishing a Department-run oyster shell recycling program. The Department-subcontractor combined program, however, offers the advantage of flexibility to an oyster shell collection program. This approach does not require high initial investment costs. Further, because it uses a private subcontractor and existing Department resources, the program may be discontinued at any time without concerns for the potential loss associated with liquidating fixed assets like dump trucks, trailers, and tractors.

Conclusions

This chapter considered the costs of alternative cultch collection and deposition programs. Hiring a private contractor to acquire and deposit cultch is generally the less expensive method for public reef enhancement and development. An oyster shell collection and deposition program, operating within Terrebonne Parish, is a feasible, if not low cost, alternative if operated solely by the Louisiana Department of Wildlife and Fisheries (or in cooperation with a subcontractor).

An additional consideration is the productive potential of the various cultch materials: oyster shells, crushed concrete, and crushed limestone. Knowledge of their productivity obtained from experiments described in Chapter 2-6 may be used to calculate benefit-cost estimates that facilitate an informed analysis.

Chapter 2-6. Cultch Materials

Cultch Material Experiment: Lake Borgne, Louisiana, Test Plots

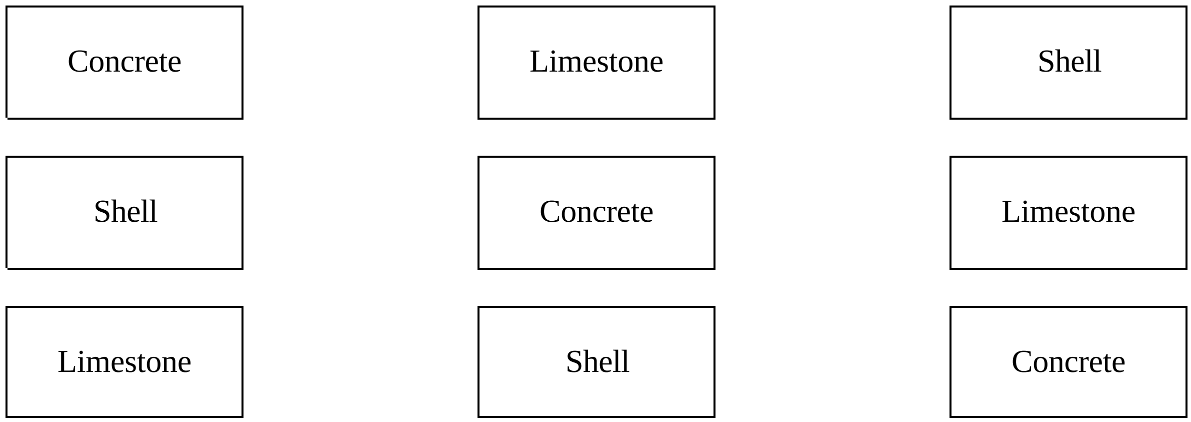
The selection of a recommended cultch material will be based upon research in the topic of comparative cultch productivity. It will focus on the results of a study of oyster growth on three types of cultch -- crushed concrete, limestone, and crushed oyster shell -- conducted by the Louisiana Department of Wildlife and Fisheries near Half Moon Island in Lake Borgne, Louisiana. These results will be used to identify the most cost effective of these materials for recommended use as oyster cultch.

The Louisiana Department of Wildlife and Fisheries identified three cultch materials for analysis as potential cultch material: crushed concrete (#57), crushed limestone (#57), and crushed oyster shells. All materials were purchased, handled, transported, and deposited by the Pontchartrain Materials Corporation (P.M.C.) of New Orleans, Louisiana. The Department elected to use crushed materials to assure a cultch size conducive to producing single oysters, thereby reducing harvester labor costs.

The comparative assessment of the three cultch materials was conducted by Cirino Consulting Services of Ocean Springs, Mississippi, under the direction of the Louisiana Department of Wildlife and Fisheries Marine Fisheries Division.[9] On October 3, 2000, P.M.C. deposited three test plots of each material in three rows, varying placement within each column to account for differences in environmental conditions (Figure 2-28). Each test plot consisted of approximately 66.6 cubic yards and covered roughly one-half acre. The test plots were closely arranged (average North-South distance = 165 feet;

[9] A full report of the Lake Borgne experiment may be found in *Performance Assessment of Three Different Cultch Materials for Public Seed Production at the Half-Moon Island Plant Site* by Cirino Consulting Services, Ocean Springs, Mississippi, July 25, 2002.

Figure 2-28. Schematic of Test Plot Site, Half Moon Island, Lake Borgne, Louisiana



average East-West distance = 196 feet) in an area adjacent to a larger plant (approximately 70 acres) of mixed crushed concrete, limestone, and oyster shell also deposited in 2000.

On June 7, 12, and 28, 2002, SCUBA divers took three one-third square meter (0.33 m^2) samples of each test plot, giving nine observations per material. Measurements were taken of oyster size and abundance in each sample (Table 2-16).

The average oyster size was slightly more than one inch (25 mm = 1 inch), and would thus be classified as seed oysters. Cirino (Section 4 of this report) reported no significant differences in the average size of oysters between the crushed concrete and oyster shell samples, but average size of oysters on both crushed concrete (34.3 mm) and oyster shells (34.6 mm) were significantly larger than those on limestone (30.5 mm).

Table 2-16. Average Size and Abundance per Sampling Portion (0.33 m^2)

	Crushed Concrete	Crushed Limestone	Crushed Oyster Shell
No. Observations	9	9	9
Average Number of Live Oysters	143.2	103.2	28.8
Average Size (mm)	34.3	30.5	34.6

The number of live oysters on concrete and limestone were not significantly different. This finding is consistent with the comparison of the two materials conducted in Barataria Bay, Louisiana by Soniat, *et al.* (1991).

Results indicated that there were significantly fewer oysters on crushed oyster shell than on either of the other materials. Several possible explanations exist for this lower productivity. One is the reduction in the volume of material (an estimated 40 percent) during the crushing process. Another may lie in alterations in the density, mass, or structure of the crushed shell. The relatively low productivity of crushed oyster shell had been noticed earlier under different circumstances. Lunz (1958) found that dredged shell (with a high portion of fragmented shell) attracted fewer oysters than oysters from processing plants (with a low portion of fragmented shell) in a cultch comparison in South Carolina.

Economic Assessment of the Test Plot Materials

The economic assessment of the cultch materials will begin by calculating the quantity of seed oysters per dollar of cultch material on the test plots in the Lake Borgne experiment. Other economic valuation measures, such as the number of available market oysters per acre or oyster harvest per acre, are inappropriate due to a lack of data. The oysters on the test plots were not of market size. Furthermore, the oyster counts were conducted at one point in time on a small area (approximately one-half acre). These counts do not represent a season's worth of oyster harvest data or the quantity of oysters taken using commercial harvesting technology over a large working area.

The abundance of oysters has previously been expressed in terms of the number of seed oysters per one-third square meter sampling area. One can estimate the number of oysters per half-acre test plot by multiplying the number of oysters per one-third square meter (0.33 m^2) sampling area by the number of one-third square meter (0.33 m^2) areas per half-acre. Since there are 4,046.873 m^2 per acre, there are 12,140.619 one-third square meter (0.33 m^2) areas per acre[10]. As each test plot is approximately one-half acre, there are 6,070.3095 one-third square meter (0.33 m^2) areas per test plot[11]. The total number of oysters per test plot is the product of 6,070.3095 multiplied by the average number of oysters per one-third square meter (0.33 m^2) sampling area (Table 2-14).

In Table 2-17, the cost of the cultch material per test plot is based on the cost of material delivered and deposited on the test plot site in Lake Borgne in October, 2003. The total cost per test plot is the product of the quantity of material per plot, approximately 66.6 cubic yards, and the cost of a cubic yard of material.

The number of seed oysters per dollar of cultch material, based on the cost of the 2000 cultch plant, is the quotient of the estimated number of oysters per test plot divided

Table 2-17. Seed Oysters per Dollar: Three Cultch Materials (2000 Prices)

Row		Crushed Concrete	Crushed Limestone	Crushed Oyster Shell
1	Average of Seed Oysters per 0.33 m^2 Sampling Area	141.2	103.6	28.8
2	Seed Oysters per Test Plot (6,070.3095 x Row 1)	869,268.3	628,884.1	174,825
3	Cost per Cubic Yard (P.M.C. 2000 Prices)	$36.51	$36.51	$28.12
4	Cost per Test Plot (66.6 x Row 3)	$2,431.57	$2,431.57	$1,918.08
5	Seed Oysters/Dollar (Row 2)/(Row 4)	357.50	258.63	91.15

[10] 3 x 4,046.873 = 12,140.619
[11] 12,140.619/2 = 6,070.3095

by the estimated cost of material for the test plot. Crushed concrete, with the highest average number of seed oysters per sample, has the highest number of seed oysters per dollar. Crushed oyster shell, with the lowest average number of seed oysters per sample, has the lowest number of seed oysters per dollar.

Care must be exercised in interpreting these results because they come from small plots with a relatively large number of seed oysters. It is unlikely that all of these oysters will grow to harvest size. Further, it is likely these small plots experienced an especially high settlement of oyster spat that might not be replicated over a larger area.

The number of seed oysters per dollar will vary as the cost of cultch changes over time. Table 2-18 includes estimates the number of seed oysters per dollar using the cost estimates provided by the firm offering the low cost estimates for cultch delivery in 2003 (See Table 2-14). These estimates were for delivery and deposit in Breton Sound, an area close to Lake Borgne. To calculate the cost of crushed oyster shell in 2003, a five dollar crushing fee is added to the earlier cost estimate for whole oyster shells.

Using 2003 cost estimates, the relative ordering of seed oysters per dollar of cultch material remains the same as that for the 2000 test plot planting. Again, crushed

Table 2-18. Seed Oysters per Dollar: Three Cultch Materials (2003 Prices)

Row		Crushed Concrete	Crushed Limestone	Crushed Oyster Shell
1	Average Seed Oysters per 0.33 m^2 Sampling Portion	141.2	103.6	28.8
2	Seed Oysters per Test Plot (6,070.3095 x Row 1)	869,268.3	628,884.1	174,825
3	Cost per Cubic Yard (Low Cost Estimate 2003)	$38.71	$39.71	$35.71
4	Cost per Test Plot (66.6 x Row 3)	$2,578.09	$2,644.69	$2,378.29
5	Seed Oysters/Dollar (Row 2)/(Row 4)	337.18	237.79	73.09

oyster shell provides the lowest number of seed oysters per dollar and crushed concrete the highest.

Based on the Lake Borgne test plot experiment, this analysis indicates that crushed concrete is the most suitable cultch material of the three tested. Crushed oyster shells are the least suitable, due principally to their low yield.

Past experience with oyster shells in reef enhancement and development, however, has demonstrated their feasibility as cultch. The Department may elect to use whole oyster shells for reef enhancement projects for reasons beyond their capacity to produce market oysters: namely, the perceived environmental or social benefits of re-using the byproduct of oyster processing as cultch material similar to that available under natural or normal circumstances. Quantifying such environmental or social benefits is beyond the scope of this research.

When the quantity of available oyster shells is insufficient for large scale cultch plantings, this research supports the use of crushed concrete over crushed limestone. This decision is based in part on the cost of crushed concrete. An increase in the price of crushed concrete relative to crushed limestone may affect this conclusion.

Chapter 7. Summary and Conclusions

This analysis included an examination of commercial oyster harvesting and processing in Louisiana and the Gulf of Mexico. It also advanced proposals for the obtaining and deposition of cultch materials plus an analysis of an experimental testing of three cultch materials in Louisiana.

The conclusions of this report may be summarized as follows:

1. Louisiana is the leading state in the United States in terms of commercial oyster harvest but lags behind other states in oyster processing;
2. Since 1990, the increased harvest from public oyster grounds has outpaced the rate of cultch deposition on these grounds:
   - A. The excess of oyster shell removed over the quantity of cultch deposited on public reefs between 1990 and 2001 was nearly 400 thousand cubic yards;
3. According to the 2000 Louisiana Department of Wildlife and Fisheries Oyster Processor Survey:
   - A. Louisiana shucked oyster production is highest from October to March;
   - B. Processors prefer daily retrieval of shell from their facilities;
   - C. Most processors prefer that somebody else haul the shells away;
   - D. One-third of the processors stockpiled their shells;
   - E. More than half of the processors reported selling their shells.
4. According to the National Marine Fisheries Service Seafood Processor Survey, Terrebonne Parish is the parish in Louisiana with the largest number of processing plants and the largest volume of shucked oysters;

5. Because of the volume of processing and proximity of processors, Terrebonne Parish was selected as the location of a hypothetical pilot program for oyster processor shell collection:

   A Processors were willing to participate;

   B Local government was willing to cooperate.

      1. Terrebonne Parish officials made a tentative offer of land as a shell stockpiling site;

      2. Terrebonne Parish officials also assisted with the cost estimates for ground transportation from oyster processing plants to the stockpiling site.

6. The cost of the hypothetical pilot program for oyster processor shell collection in Terrebonne Parish is comparable to the cost of hiring a private contractor to deposit crushed concrete or crushed limestone in Terrebonne Parish:

   A. Using Department resources to operate such a program in whole or in part is necessary to keep the costs within a feasible range;

   B. The scope of the program is limited to public oyster grounds within Terrebonne Parish because the Department's fleet of marine vessels is unable to reach more distant locations in a timely manner.

7. Hiring a private contractor to deposit cultch material (oyster shell, crushed concrete, of crushed limestone) is the most versatile method of oyster reef enhancement:

   A. One private contractor provided the low-cost estimates for cultch deposition in areas across the state of Louisiana;

      1. This firm possesses the high-pressure hose system which has proven to be a successful method during past cultch planting activities.

B. The cost of depositing oyster shell was lower than that of crushed concrete and crushed limestone

1. The quantity of available oyster shell, however, may be insufficient for large-scale reef enhancement projects.

2. The cost of acquiring oyster shells is likely to increase with the implementation of a large-scale oyster shell cultch deposition project as a result of the increase in demand for the shells

8. An experimental analysis of three potential cultch materials near Half Moon Island in Lake Borgne, Louisiana, suggested that crushed concrete offers a larger number of seed oysters per dollar than either crushed limestone or crushed oyster shells.

9. Using crushed oyster shell as cultch is not recommended in Lake Borgne. In the Lake Borgne experiment, crushing oyster shells raised costs and lowered yields.

10. The Department, based on prior experience, may wish to use whole oyster shell as cultch for reasons beyond the production of market oysters;

A. Possible reasons include the perceived environmental or social benefits of using oyster shells;

1. Reusing oyster shells may be perceived as a socially-desirable recycling program.

B. The environmental and social benefits of using oyster shells as cultch are not quantified in this report.

11. If the Department chooses not to use oyster shells as cultch, it may employ crushed concrete or limestone.

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Section 3.

The Value of Louisiana Oyster Reefs to Recreational Fishermen

Final Report Submitted to the National Marine Fisheries Service under
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Chapter 3-1. Louisiana's Oyster Reefs as Recreational Fishing Grounds

Introduction

Oysters are important contributors to the economic and ecological welfare of the coastal communities in which they are found. Their value as economic assets is easily observable and readily quantified. Their value as ecological assets is also widely recognized for improving water quality, recycling biological materials, and providing habitat for a number of marine organisms (Milewski and Chapman, 2002).

This last function, as a sessile, reef-forming organism (Huston, 1994), has drawn special attention from many researchers and resource managers. Censuses of oyster reefs reveal that they host numerous benthic and pelagic species (Coen, Luckenbach, and Breitburg, 1999; Breitburg, *et al.*, 2000; Brumbraugh, *et al.,* 2000; Dumbauld, *et al*., 2000; Lenihan and Grabowsky, 1998; Noble, 2000; Yozzo, *et al.*, 1999), many with important commercial or recreational value (Mann, Burreson, and Baker, 1991; Mertz, 1999).

Because most recreational anglers prize quantity and diversity of catch (Kelso, Monzyk, and Rutherford, 1999), those who are aware of the species variety and abundance of fish available over oyster reefs are drawn to use them as fishing grounds. It is logical to assume that they will value oyster reefs for the enhanced recreational fishing opportunities they provide, since research has revealed that recreational anglers do attach economic value to arrangements that result in increased catch (Milon and Thunberg, 1994; Haab, Whitehead, and McConnell, 2001; Whitehead and Haab, 2001).

Previous studies of recreational fishing provide statewide or nationwide estimates of angling expenditures and activity (U.S. Department of the Interior, Fish and Wildlife

Service, 1998; Kelso, Monzyk, and Rutherford, 1999; Fedler and Leahy, 1998) and various measures of economic value (Milon and Thunberg, 1994; Haab, Whitehead, and McConnell, 2001; Whitehead and Haab, 2001). These estimates of angling activity and expenditures illustrate the degree of activity in the community, but do not reveal information about the specific resources over which shellfish resource managers have control or supervision. A measurement of the value of shellfish reefs to the recreational anglers who exploit them may be more precise and thus more helpful in the formation of shellfish resource policies and management decisions.

Louisiana, with 930 miles of coast and 3.4 million acres of water (Barrett, 1971), may be an ideal place to investigate this valuation issue. The state was the origin of 36.4 percent of the nation's commercial oyster harvest and the site of 4,113,000 recreational fishing days in 2001 (U.S. Department of the Interior, Fish and Wildlife Service, 2002.) The Louisiana Department of Wildlife and Fisheries, with the support of the National Marine Fisheries Service, sought to gain more precise insight into the economics of recreational fishing over oyster reefs, and established a study with three principal aims:

1. to develop a profile of Louisiana resident anglers who fish over oyster reefs;
2. to determine the anglers' reasons for using the oyster reefs, and;
3. to estimate the value of oyster reefs as recreational fishing grounds among Louisiana resident anglers.

To achieve these research goals, the Louisiana Department of Wildlife and Fisheries Socioeconomic Research and Development Section used data derived from a sample of Louisiana residents who participated in the National Marine Fishery Service (N.M.F.S.) 2000 Marine Recreational Fishing Statistical Survey (M.R.F.S.S.) and a connected telephone survey conducted by the Department of Wildlife and Fisheries. These instruments collected personal characteristics of the respondent and his or her angling experience and elicited the respondent's willingness to pay to maintain the ability to fish over Louisiana oyster reefs.

Commercial Oyster Harvests

Because the most commonly acknowledged function of oyster reefs is the provision of seafood for human consumption, the analysis of oyster reefs as recreational fishing grounds should also include a description of commercial oyster harvesting. Doing so places recreational angling, a secondary economic activity, in the context of the primary economic activity, commercial shellfish production.

Domestic production, minus exports, combined with imported oysters, yields estimates of U.S. oyster consumption of 71.4 million pounds in 2000 and 58.1 million pounds in 2001. Annual per capita consumption of oysters in the U.S. during these years ranged from three to four ounces, a decline from four to five ounces per person in the 1980's (Johnson, 2000; House, Hanson, Sureshwaran, 2003).

Commercial harvests of oysters in the U.S. in 2002 totaled 34.71 million pounds (of meat) and were valued at $88.8 million in dockside value ($80.3 million in 1996 dollars). The five-year average commercial harvest for 1997 – 2001 was 35.5 million pounds with a dockside value of $86.6 million (in 1996 dollars)[1].

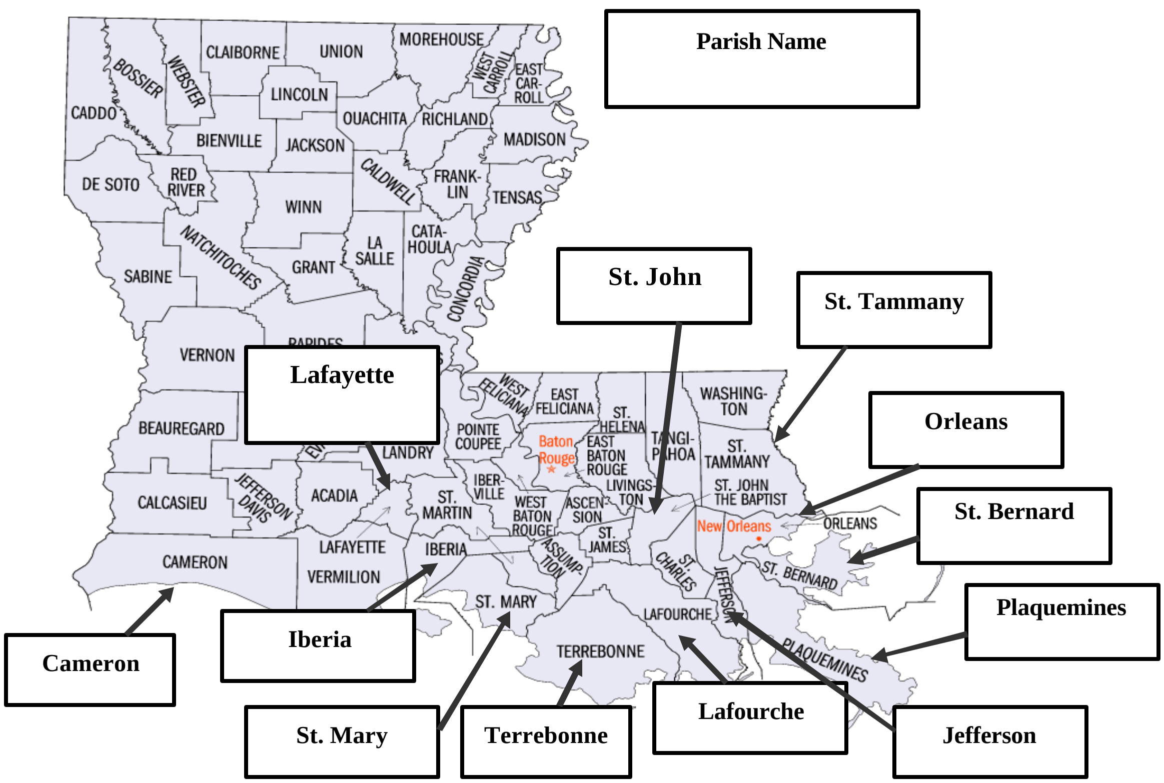
Louisiana is the leader among all states in commercial oyster harvesting. The state produced 13.96 million pounds of oyster meat in 2002 worth $30.3 million ($27.4

[1] All dollar values in this report deflated or adjusted for inflation using the Bureau of Economic Analysis Inflation Deflator, expressed in 1996 dollars, the current B.E.A. "base year."

million in 1996 dollars), somewhat below the 1997 – 2001 five-year average of 12.6 million pounds valued at $26.3 million in 1996 dollars. Oyster landings in 2001 comprised 9.91 percent of total value (in dollars) of the state's commercial seafood landings and were the fifth most valuable commercial marine species in Louisiana behind white shrimp, brown shrimp, menhaden, and blue crab (N.M.F.S. Fisheries Statistics and Economics Division, 2003).

Louisiana oyster production remains most concentrated in three southeastern coastal parishes, Plaquemines, St. Bernard, and Terrebonne. Together these account for three-quarters of the state's commercial harvest (Figure 3-1).

Figure 3-1. Parish of First Sale for Commercial Oyster Harvests, 2001



Data Source: Louisiana Department of Wildlife and Fisheries
Map Source: U.S. Census Bureau

Previous Economic Studies of Oyster Reefs

Beyond the compilation of commercial harvest statistics, oysters have received a fair amount of prior economic analysis. Most of this has been in the form of harvesting cost studies (MacKenzie, 1983; Berrigan, 1988; Dugas and Lavergne, 1997) and feasibility studies of shellfish reef enhancement or rehabilitation efforts (Martinez, Dimichele, and Ray, 1992; Louisiana Department of Wildlife and Fisheries, 1993; Soniat, Broadhurst, and Haywood, 1991).

Economic impact studies have produced a series of multipliers for investments in oyster reef enhancement projects. Berrigan (1990) identifies a Texas study that reports that every dollar of direct input produces $3.12 of economic output. Posadas, *et al.*, (1991) present an economic impact multiplier estimate for Louisiana oyster reefs of 2.03.

An economic study of Louisiana oystermen in Barataria Bay (Melancon and Condrey, 1992) examined the cost of oyster seed bedding and harvesting. Fixed costs were 27 percent of all expenses. Labor (58 percent of all expenses) was the highest of all categories, ahead of repairs (16 percent) and fuel (12 percent).

Keithly, Roberts, and Brannan (1992) examined transfers from oyster leases. Keithly, Diagne, and Dugas (2000) determined that oyster relaying (moving oysters from leases under compromised water quality to leases in cleaner, approved waters before final harvest) was positively related to public reef production and private reef production.

Lenihan and Grabowski (1998) investigated the value of North Carolina oyster reefs as habitat for other commercial fishery species, namely, crabs and various finfish. They estimated that the productive value of oyster reefs exceeded that of the commercial oyster harvest on the small, heavily damaged reefs near the Neuse River, Ocracoke Island, and Pamlico Sound.

The Outline of this Report

This investigation of the value of oyster reefs as recreational fishing grounds to Louisiana resident anglers begins by examining the scientific evidence of their potential as marine habitat (Chapter 3-2). A description of the Louisiana recreational fishery (Chapter 3-3) illustrates the scope of activity in the recreational angling sector and provides context for the valuation study. A summary of economic concepts and a description of economic valuation techniques (Chapter 3-4) precede the empirical estimation of the value of Louisiana oyster reefs to resident anglers (Chapter 3-5). A summary of this research and possible areas for future investigation (Chapter 3-6) conclude the report.

Chapter 3-2. Oyster Reefs as Marine Habitat

As notable as the commercial oyster fishery statistics are, the value of oyster reefs extends beyond the commercial harvests they provide. Oysters perform several important ecological functions in coastal marine ecosystems: filtering water, recycling biological material, boosting benthic productivity, and processing phytoplankton into other useful forms (Milewski and Chapman, 2002.) Perhaps most notably, as sessile organisms, they create feeding and nesting habitat for mobile species, attachment sites for other benthic species, and protective cover from predation for numerous species (Coen, Luckenbach, and Breitburg, 1998; Breitburg, *et al.*, 2000).

In recognition of their central part in the maintenance and stability of their coastal ecosystems, oysters have been labeled "keystone species" (or "cornerstone species") in selected marine environments. As a keystone supports an arch, keystone species support a complex community of species by performing a number of functions essential to the diverse array of species that surround them.

Sea otters on the U.S. Pacific coast, for example, have been labeled keystone species because they keep sea urchin populations in check. Elephants in the savannahs and dry woodlands of Africa are considered keystone species because they break or uproot thickly grown trees, making room for grasses and shrubs and enhancing habitat opportunities for other species (Wilson, 1992). Oysters are keystone species because they serve as nourishment and habitat for a variety of other species in tidal and sub-tidal marine environs (Milewski and Chapman, 2002; National Oceanographic Administration and National Marine Fisheries Service, 2002).

The reef-building capacity of oysters is central to their designation as "structural species," another conceptualization of ecosystem organization of their ecological importance (Huston, 1994). As trees provide infrastructure in a forest, the physical environment around and within which other species live and prosper, oysters are "ecosystem engineers" (Milewski and Chapman, 2002) in the marine environment, building three dimensional structures that thrust from the bottom up into the water column. Oyster reefs feed, shelter, and house a diversity of species, prompting Lenihan and Grabowski (1998) to identify them as a "good temperate latitude analogue to coral reefs (p. 22)."

Biological Surveys of Oyster Reef Communities

Biological surveys of oyster reefs reveal their productive capacity. Lenihan and Grabowski (1998) identified nineteen species that utilize oyster reefs in North Carolina, including such important commercial and recreational species as blue crab, spotted sea trout, southern flounder, and pompano (Table 3-1). Noble's study (2000) of North Carolina reefs lists seventeen species in oyster communities including clams, mussels, starfish, red drum and striped bass, and even terrestrial species (Table 3-2).

Table 3-1. Species Utilizing Oyster Reefs: North Carolina

Blue Crab	Pig Fish	American Eel	Sheepshead
Spadefish	Spotted Sea Trout	Weakfish	Spot
Croaker	Gag Grouper	Southern Flounder	Black Drum
Bluefish	Spanish Mackerel	Pompano	Toadfish
Gray Snapper	Silver Perch	Pinfish	

Source: Lenihan and Grabowski, 1998

Table 3-2. Species Included in Oyster Communities: North Carolina

Clams	Mussels	Anemones	Polychaetes
Amphipods	Sponges	Crabs	Red Drum
Black Drum	Striped Bass	Sheepshead	Spotted Sea Trout
Flounder	Oyster Toads	Starfish	Sea Urchin
Whelks	Raccoons	Wading Birds	

Source: Noble, 2000

Different species utilize oyster reefs in different ways which may be categorized according to the species' tenure on the reef. Resident species generally remain on the reefs and use the structure for shelter. Facultative residents make regular use of the reefs, alternatively venturing off and returning to them, but mostly depending upon the reefs for food and shelter. Transient species exploit the reefs when available but can readily travel to and reside in alternative habitats.

A listing of fish species by Yozzo, *et al.* (1999) (Table 3-3) reports five resident, five facultative resident, and twenty transient species found over oyster reefs along the Atlantic coast. On oyster reefs along the Texas coast (Table 3-4), Zimmermann, *et al.*

Table 3-3. Species Utilizing Oyster Reefs on the Atlantic Coast: Residents, Facultative Residents, and Transients

Residents	Facultative Residents	Transients	
Naked Goby	Black Sea Bass	Striped Bass	Pigfish
Oyster Toadfish	Northern Pikefish	Summer Flounder	Silver Perch
Skilletfish	Atlantic Spadefish	Winter Flounder	Spotted Hake
Striped Blenny	Darter Goby	Northern Puffer	Spot
Feather Blenny	Seaboard Goby	Inshore Lizardfish	Butterfish
		American Eel	Hogchoaker
		Striped Burrfish	Bay Anchovy
		Atlantic Silverside	Common Carp
		Atlantic Croaker	Pinfish
		Atlantic Menhaden	
		Northern Sea Robin	

Source: Yozzo, *et al.*, 1999

Table 3-4. Species Utilizing Oyster Reefs on the Texas Coast: Residents and Transients

Resident Species	Transient Fishes	Transient Decapod Crustaceans
Gulf Toadfish	Speckled Worm Eel	Pink Shrimp
Naked Goby	Gulf Menhaden	Blue Crab
Skilletfish	Bay Anchovy	Marsh Grass Shrimp
Striped Blenny	Inland Silverside	Daggerblade Grass Shrimp
Freckled Blenny	Bighead Searobin	
	Green Sunfish	
	Sheepshead	
	Pinfish	
	Striped Mullet	

Source: Zimmerman, Minello, Baumer, and Castiglione *in* Coen, Luckenbach, and Breitburg, 1999

(in Coen, Luckenbach, and Breitburg, 1999) identify five resident species, nine transient species, and four transient decapod crustaceans.

A study of four bays in New Brunswick, Canada revealed a diversity of species over the oyster beds there. The average number of species per sample ranged from eleven in Caraquet Bay to twenty-seven in Cocagne Bay (Milewski and Chapman, 2002).

Studies of reefs have demonstrated the capacity for fixed structures to improve not only the quantity but also the quality of available fish. Lane snapper in the northeastern Gulf of Mexico grow faster over reefs than over bare bottom. Red snapper also grow larger and live longer over reefs (Szedlmayer, 2000a). Compared to those over open water bottoms, reef-resident red snapper and gray triggerfish consume a diet that seems to support a faster growth rate (Szedlmayer, Fall, 2000).

Conclusion

A growing appreciation of the biological role of oyster reefs comes as many oyster stocks along the U.S. Atlantic coast are in decline due to predation, over-harvesting, disease, and environmental degradation (Coen, Luckenbach, and Breitburg, 1999; Hargis and Haven, 1988; Cook, *et al.*, 2000). This decline has precipitated concerns for the loss of economic activity and the deterioration in marine habitat (Breitburg, *et al.*, 2000).

Commercial growers have joined recreational angling organizations and civic groups in promoting shellfish restoration in an effort to rebuild reefs for commercial harvesting (Hargis and Haven, 1988; Perret and Chatry, 1988), bioindicators (Dewey, 2000), and marine habitat enhancement (Chesapeake Bay Foundation, 2000; Milewski and Chapman, 2002).

These efforts at oyster reef enhancement should consider the value of all the biological functions of oysters. Commercial harvests and related activities, such as processing, are essential components in many regions, but are not the only valuable element of oyster reefs. Many of the species that reside on oyster reefs have demonstrated value as targets of recreational activity. An effort at evaluating the use of oyster reefs by fish and anglers is in order.

Chapter 3-3. Recreational Fishing in Louisiana

Introduction

Fishing is a source of recreation and relaxation for hundreds of thousands of residents and visitors to the state of Louisiana. Expenditures associated with fishing, for myriad items such as boats, rods, reels, fuel, food, and lodging, reach into the hundreds of millions of dollars. Estimates of participation and expenditures vary according to survey method and format. Several examples provided below present an estimated range of participation and expenditures.

Participation Estimates: Louisiana Department of Wildlife and Fisheries License Issuance

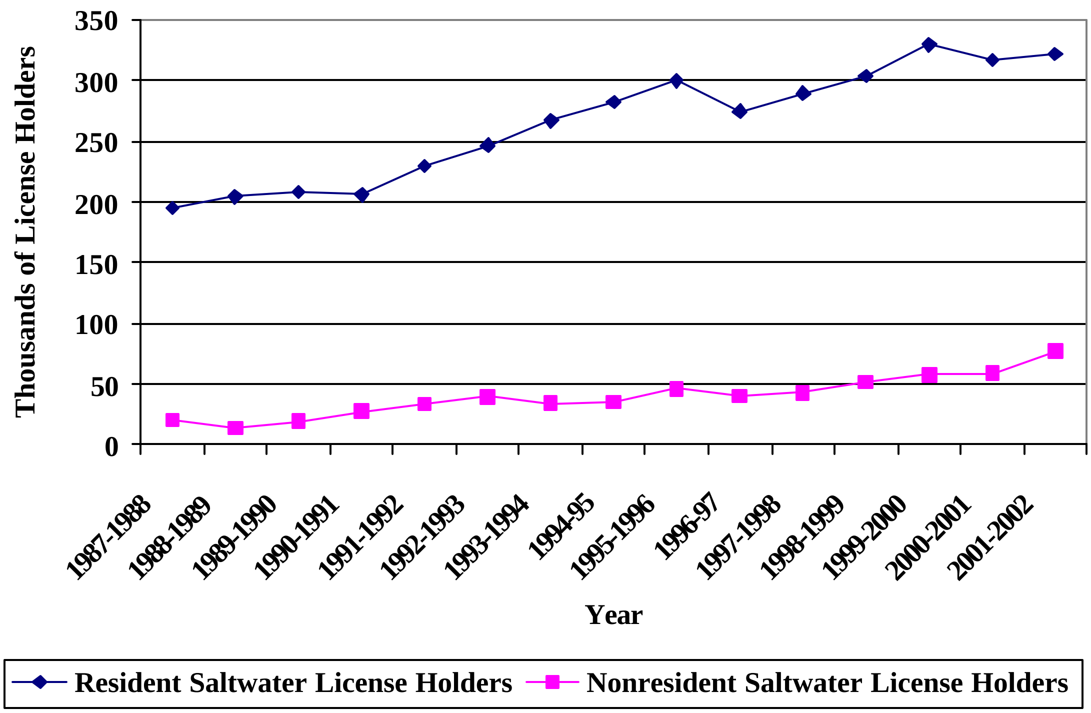
The Louisiana Department of Wildlife and Fisheries maintains responsibility for managing the state's aquatic and terrestrial resources for the protection, conservation, and replenishment of wildlife and aquatic life and for the people who utilize them. The Department possesses authority to issue recreational hunting, fishing, and trapping licenses, boat registrations, and commercial harvester and dealer licenses for various species of fish and wildlife.

Since fiscal year 1984–85, the state has required the purchase of a saltwater recreational fishing license in addition to a basic fishing license for all resident and non-resident saltwater anglers who are required to be licensed. Prior to that time, there was not a specific or separate recreational license for saltwater fishing, only a basic recreational fishing license that allowed both freshwater and saltwater recreational fishing. Since 1987-88, there have been separate saltwater licenses for residents and non-residents.

The Louisiana Department of Wildlife and Fisheries issues fishing licenses to more than one-half million recreational anglers each year. There has been some variance, from 502,483 in fiscal year 1987–88 to 604,309 in fiscal year 1995-96 to 518,814 in fiscal year 2001–02. The trend has followed a steady trajectory to a minor decline. Resident saltwater recreational licenses issued have increased from 195,099 in fiscal year 1987-88 to 322,107 in fiscal year 2001-02 (Figure 3-2).

The issuance of recreational fishing licenses to non-residents has increased markedly in recent years. Non-resident licensed anglers (freshwater and saltwater) have risen from 45,246 in fiscal year 1987-88 to 112,835 in fiscal year 2001-02. Non-residents obtained 20,647 recreational saltwater licenses (Figure 3-2) in fiscal year 1987–88 and 77,273 in fiscal year 2001 – 2002.

Figure 3-2. Louisiana Department of Wildlife and Fisheries Saltwater Recreational Fishing Licenses: Residents and Non-Residents



For a variety of reasons, the number of licenses issued probably underestimates the number of saltwater anglers. In Louisiana, resident and non-resident anglers under 16 and residents born prior to June 1, 1940 are exempt from licensing requirements and thus are not included in license statistics. Furthermore, many people who are required to hold a license may nevertheless fish without one. The U.S. Fish and Wildlife Service (1996) estimates that only 66 percent of all anglers hold at least one license. If this is true for Louisiana, the number of licenses issued may represent only two-thirds of the population of anglers.

Participation Estimates: U.S. Fish and Wildlife Service

The U.S. Fish and Wildlife Service (U.S.F.W.S.) estimates the participation in fishing, hunting and other wildlife-related recreational activities through a nation-wide telephone survey of randomly selected households in every state. This survey is conducted every five years and thus provides an image of contemporary recreational activities as well as a comparison to other time periods.

Estimated Number of Anglers: U.S. Fish and Wildlife Service

The 2001 National Hunting, Fishing, and Wildlife-Related Recreation Survey estimated 970,000 participants (757,000 residents and 217,000 non-residents) in all fishing (freshwater and saltwater) in Louisiana (Table 3-5). There were 504,000 saltwater anglers, including 386,000 resident saltwater anglers (Table 3-6) (U.S. Department of the Interior, Fish and Wildlife Service, 2002).

Table 3-5. U.S. Fish and Wildlife Services Estimates of Angling Activities in Louisiana: 2001

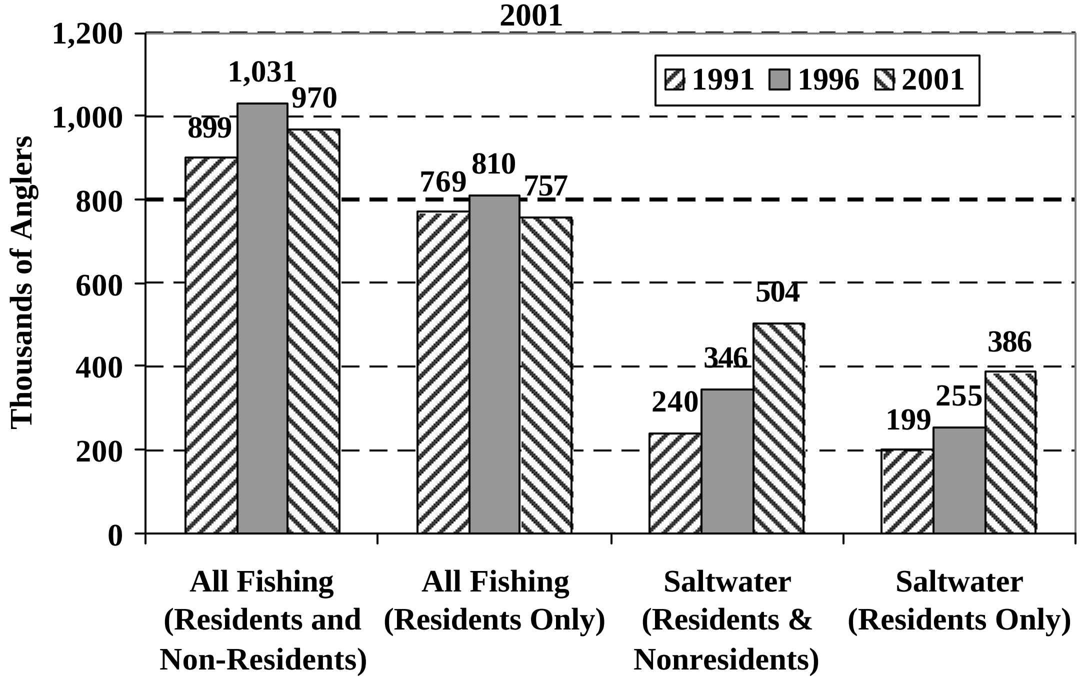
All Fishing; Activity in State by Residents and Non-Residents	
	2001
Anglers (in thousands)	970
Angling Trips (in thousands)	11,558
Angling Days (in thousands)	12,637
Average Days	13
Saltwater Fishing; Activity in State by Residents and Non-Residents	
	2001
Anglers (in thousands)	504
Angling Trips (in thousands)	4,080
Angling Days (in thousands)	4,673
Average Days	9
Source: U.S. Fish and Wildlife Service, 2002	

Table 3-6. U.S. Fish and Wildlife Services Estimates of Saltwater Angling Activities by Louisiana Residents: 2001

All Fishing; Activity in State by Residents Only	
	2001
Anglers (in thousands)	757
Angling Trips (in thousands)	10,978
Angling Days (in thousands)	11,691
Average Days	15
Saltwater Fishing; Activity in State by Residents	
	2001
Anglers (in thousands)	386
Angling Trips (in thousands)	3,766
Angling Days (in thousands)	4,113
Average Days	11
Source: U.S. Department of the Interior, Fish and Wildlife Service, 2002	

According to the National Hunting, Fishing, and Wildlife-Related Survey data, there has been a decline in the number of anglers for all fishing in Louisiana (freshwater and saltwater) from 1996 to 2001 (Figure 3-3), reversing an upward trend from 1991 to1996. Contrary to the decline in participation in all fishing, saltwater angling in Louisiana has experienced an increase in the number of participants. The estimated number of saltwater anglers in Louisiana in 1996 was 346,000, including 255,000

Figure 3-3. Number of Anglers in Louisiana, All Fishing and Saltwater Fishing: Residents and Non-Residents: 1991, 1996, 2001



Source: U.S. Department of the Interior, Fish and Wildlife Service, 1993, 1996, 2002

residents. The estimated number of saltwater anglers rose to 504,000 in 2001, including 386,000 resident saltwater anglers.

As expected, the U.S.F.W.S. estimate of the number of participants in recreational saltwater angling in 2001 exceed the number of saltwater angling licenses issued by the Louisiana Department of Wildlife and Fisheries. The number of licensed resident saltwater anglers was 316,996 in fiscal year 2000 – 2001 and 322,107 in fiscal year 2001-2002, beneath the U.S.F.W.S. estimate of 386,000 resident saltwater anglers in 2001. While the U.S.F.W.S. estimated 118,000 non-resident saltwater anglers in Louisiana in 2001, the Louisiana Department of Wildlife and Fisheries issued 58,911 saltwater angling licenses to non-residents in fiscal year 2000 – 2001 and 77,273 in fiscal year 2001 – 2002.

The relationship between the Louisiana Department of Wildlife and Fisheries resident license issuance and the U.S.F.W.S. estimates for resident saltwater recreational anglers was reversed in 1996. The Department of Wildlife and Fisheries issued 299,867 resident saltwater fishing licenses in fiscal year 1995–96 and 274,728 in 1996–97. Both of these exceed the U.S.F.W.S. estimates for the number of resident saltwater anglers in 1996 (255,000). This relationship is contrary to the expectation that participation would exceed the number of saltwater recreational licenses.

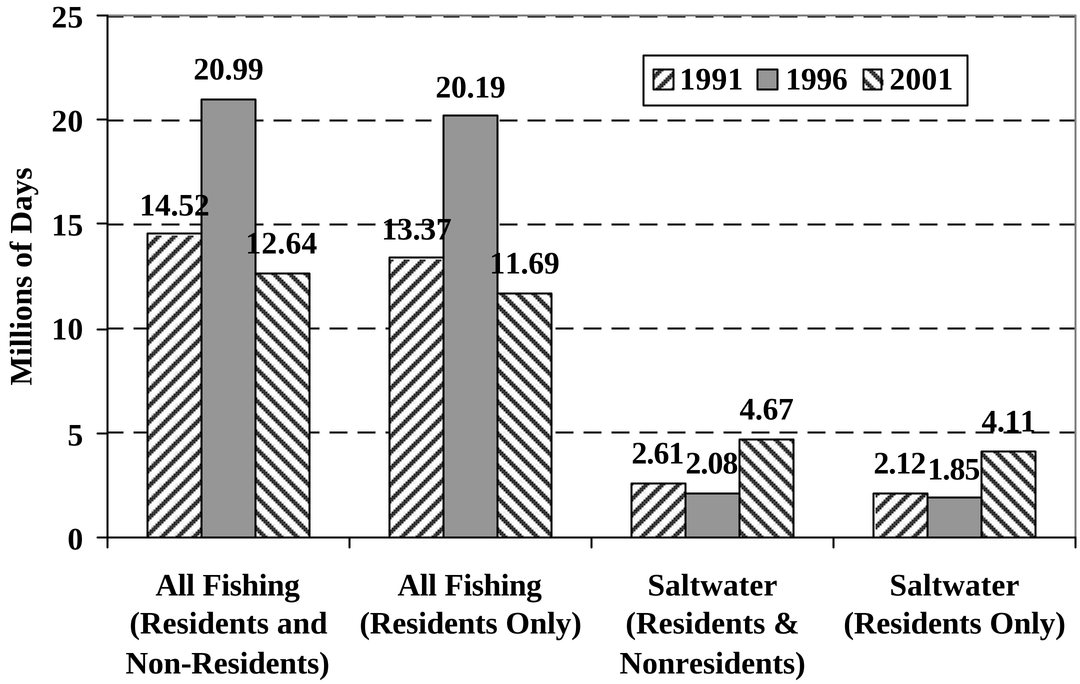
The number of non-resident saltwater angling licenses issued in fiscal year 1995 – 1996 (46,239) and fiscal year 1996 – 1997 (39,981) were far below the U.S.F.W.S. estimate for the number of non-resident saltwater anglers (91,000) in 1996.

Estimated Number of Fishing Days: U.S. Fish and Wildlife Service

In 2001, Louisiana was the site of 7.96 million freshwater fishing days and 4.67 million saltwater fishing days. Louisiana residents spent 4.11 million days saltwater fishing, 88 percent of all saltwater angling days in the state (U.S. Department of the Interior, Fish and Wildlife Service, 2002).

For all fishing there has been a decline in recreational fishing effort. The number of angling days fell by over eight million (Figure 3-4) from 1996 to 2001, due to a decline in the estimated number of angling days among Louisiana resident anglers. In contrast, saltwater recreational effort in Louisiana rose from 2.08 million saltwater angling days in 1996 to 4.67 million days in 2001. The number of saltwater angling days

Figure 3-4. Angling Days in Louisiana, All Fishing and Saltwater Fishing: Residents and Non-Residents: 1991, 1996, 2001



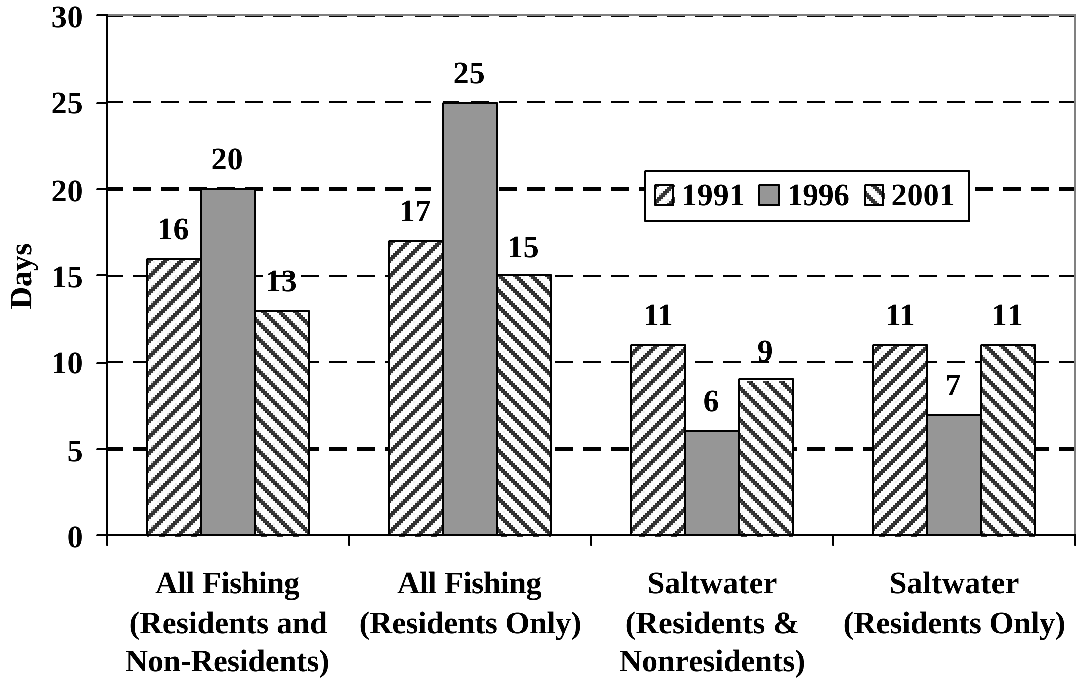
Source: U.S. Department of the Interior, Fish and Wildlife Service, 1993, 1996, 2002

by Louisiana residents doubled from 1.85 million days in 1996 to 4.11 million days in 2001. (U.S. Department of the Interior, Fish and Wildlife Service, 1993,; U.S. Department of the Interior, Fish and Wildlife Service, 1998; U.S. Department of the Interior, Fish and Wildlife Service, 2002).

The average number of days of all types of fishing in Louisiana has likewise declined. The average number of days spent fishing by residents and non-residents fell from 20 in 1996 to 13 in 2001 (Figure 3-5). The average number of days spent in all fishing in Louisiana by state residents fell from 25 in 1996 to 15 in 2001.

Again, the estimates for saltwater angling in particular contrast with this observed decline for all fishing. The average number of days in saltwater fishing rose from 6 in

Figure 3-5. Average Number of Angling Days, All Fishing and Saltwater Fishing: Residents and Non-Residents: 1991, 1996, 2001



Source: U.S. Fish and Wildlife Service, 1993, 1996, 2002

1996 to 9 in 2001 for all saltwater anglers (residents and non-residents). The average rose from 7 to 11 for Louisiana residents.

Estimated Angling Expenditures: U.S. Fish and Wildlife Service

According to U.S.F.W.S. estimates for 2001, total angling expenditures in Louisiana were $703.4 million, with $398.8 million spent on trip-related items, $272.1 million on equipment, and $32.5 million on boats, campers, cabins, and other special equipment.

Saltwater anglers spent 41.5 percent of all trip-related and equipment expenditures in 2001. These anglers spent $222.1 million on trip-related items and $56.6 million on equipment for the purpose of saltwater recreational fishing.

Participation Estimates: National Marine Fisheries Services

A third source for information regarding recreational fishing participation comes from the Fisheries Statistics and Economics Division within the National Marine Fisheries Service (N.M.F.S.). The data from the Marine Recreational Fisheries Statistics (M.R.F.S.) Survey is collected through two different formats. The M.R.F.S. (or “Intercept”) Survey is administered to recreational anglers intercepted on their return from marine fishing trips in all coastal states except Texas. The Telephone Survey is directed to randomly selected households in coastal counties or parishes around the country. A follow-up telephone survey to a sub-sample of those anglers who participated in the Intercept Survey is also conducted.

Estimated Number of Anglers: National Marine Fisheries Service

The N.M.F.S. estimate for Louisiana saltwater anglers in 2001 (775,716) is 54 percent greater than the estimate of the U.S. Fish and Wildlife Service (504,000). The N.M.F.S. estimate for Louisiana resident saltwater anglers only (653,000) is 69.2 percent greater than the U.S.F.W.S. estimate for resident saltwater anglers (386,000).

Estimated Number of Fishing Days: National Marine Fisheries Service

According to the National Marine Fisheries Service, Louisiana, with 3.62 million saltwater fishing trips, is eighth in the Union and second among states in the Gulf of Mexico in 2001.

Estimated Angling Expenditures: National Marine Fisheries Service

The National Marine Fisheries Service has analyzed expenditure data to estimate the total expenditures on saltwater angling in coastal states. Estimated Louisiana saltwater angling expenditures in 2001 totaled $1.18 billion, second among Gulf of

Mexico states behind Florida ($4.45 billion). This estimate for Louisiana saltwater expenditures is nearly twice the $703.4 million estimate for all fishing expenditures in Louisiana provided by the U.S. Fish and Wildlife Service.

Spending is categorized as trip-related expenditures (for items associated with a single outing) or equipment or durable expenditures for longer-lived items. In all states throughout the Gulf of Mexico, total expenditures for both residents and non-residents on equipment and durable goods is much larger than total spending on trip-related items, such as food, fuel, lodging, and bait.

Trip-related spending is further categorized according to the mode of the angler: private or rented boat, charter boat, or shore. Anglers in private or rented boats incurred $120 million of trip-related expenditures, 78 percent of all resident angler trip-related expenditures. Louisiana residents spent $26.96 million on shore fishing trip-related expenses and $5.35 million on charter boat trip-related expenses. Louisiana is unique in the Gulf as the only state for which resident charter boat trip-related expenditures outweigh non-resident charter boat trip-related expenses ($3.21 million).

Conclusion

Saltwater angling is a common form of recreation in Louisiana, enjoyed by hundreds of thousands of people for millions of fishing days each year. Expenditure estimates indicate that the pursuit of recreational fish contributes millions of dollars to the state economy. These figures present an image of the scope and scale of activity in the state.

The presence of popular species of recreational fish over oyster reefs suggests the potential of the reefs' value as fishing grounds. The two most targeted popular species in

Louisiana, spotted seatrout and red drum, are commonly found above oyster reefs, a factor that may contribute to their popularity and value. Three-quarters (76 percent) of the respondents to the Kelso, Monzyk, and Rutherford (1999) saltwater angling survey targeted a particular species of fish. Of these, 49 percent targeted spotted seatrout and 39 percent targeted red drum.

Previous studies have linked increased catch rates to increases in the value of recreational fishing (Haab, Whitehead, and McConnell, 2001; Strand, *et al.*, 1991; McConnell and Strand, 1994). Since oyster reefs are also identified as producing a large quantity of fish, they may indeed hold value as recreational fishing grounds.

An accurate accounting of the recreational value of oyster reefs must go beyond activity and expenditure estimates. A variety of non-market valuation techniques are available to generate such an estimate.

Chapter 3-4. Non-Market Valuation: Concepts and Methods

Introduction

Researchers analyzing recreational angling, like other natural resource-based commodities, frequently employ non-market valuation techniques when market data are hard to find or unreliable as a true measure of economic value. Economists have identified incomplete or attenuated property rights that contribute to the kinds of market failure that necessitate the use of non-market valuation techniques.

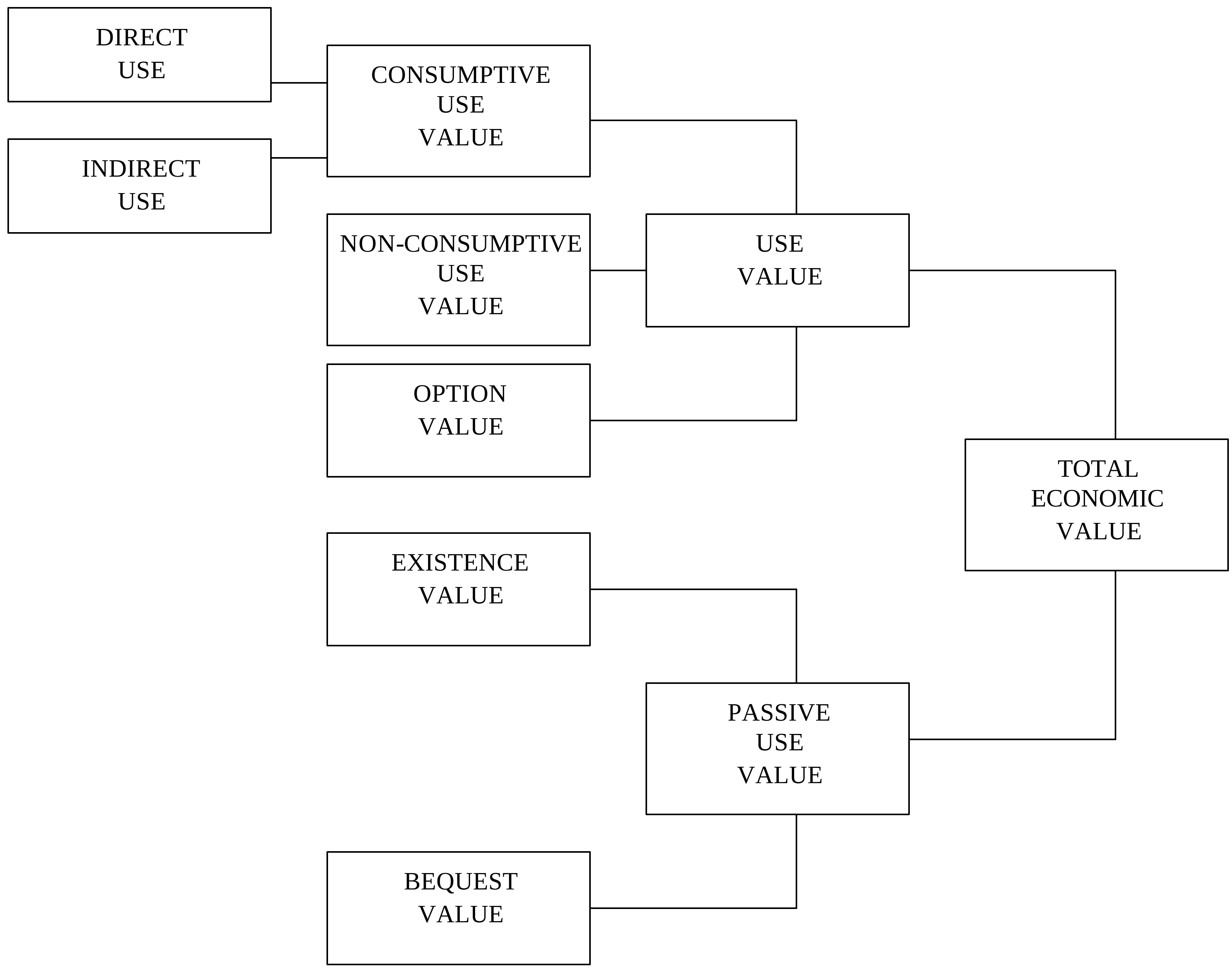
Non-market valuation techniques may be based on actual market transactions (revealed preference) or on direct responses from individual respondents (stated preference). This research contains an application of the contingent valuation method, a commonly used stated preference method that elicits willingness to pay as a measure of the value of specified natural resources.

Total Economic Value

An economic investigation into a multi-dimensional amenity like oyster reefs should consider the "total economic value" approach. Under this conceptual framework, the economic value of oyster reefs is divided into two basic components: use values and non-use (or passive use) values (Figure 3-6).

Passive use values are those that are not associated with the utilization of a resource. Its sub-components are existence value (the value derived from knowing an amenity exists although one does not plan to use it) and bequest value (the value of knowing a resource exists for potential enjoyment by future generations.)

Figure 3-6. Total Use Value Framework



Use values, those values associated with the utilization of a resource, can be divided into sub-components: consumptive use value, non-consumptive use value, and option value. Consumptive use value is associated with the actual taking or harvesting of a resource, such as hunting, mining, or forestry. Non-consumptive use values are associated with activities that involve the use, but not the taking of a resource, such as bird-watching, sight-seeing, or hiking. Option value is the value of maintaining a resource for future use, though one may not currently use it (Turner, 1991; Weisbrod, 1964; Krutilla, 1967).

Consumptive use value may be further divided among direct and indirect values. A forest may have direct consumptive use values, providing timber, and indirect consumptive use value, habitat for deer that will be hunted. Commercial oyster harvests are part of direct consumptive use value. Recreational fishing over oyster reefs might be categorized as indirect consumptive use value.

Property Rights and Market Failure

The ability of markets to allocate resources efficiently is contingent upon the existence of prices that reflect the full value of the products produced (output) and the resources used in production (inputs). This condition will evolve only when the property rights surrounding inputs and outputs are complete or non-attenuated. "Non-attenuated property rights" are present only when the goods are exclusive (assigned to one clearly identified person or party) and rival (consumption by one person or party reduces the quantity available to others). These conditions are satisfied for a variety of consumer

An Alternative Characterization of Property Rights

A slightly more complex characterization of property rights regimes, described in Tietenberg (1988), identifies non-attenuated property rights as:

1. Universal – Resources are privately owned. Rights are clearly defined and completely specified.
2. Exclusive – All benefits and costs accrue to the owner.
3. Transferable – All property rights are transferable from one person to another in voluntary exchange.
4. Enforceable – Property rights are secure from involuntary seizure and encroachment.

goods that are regularly traded efficiently through the workings of the market (Randall, 1993).

When property rights are incomplete or attenuated, markets may not generate an efficient distribution. For goods with non-exclusive property rights, those that may not be assigned entirely to one person or party, the frequent result is over-use or excessive exploitation, a typical fate for common property resources.

For non-rival goods, consumption does not automatically reduce the amount available to others. As such, once some quantity of a non-rival good is produced, the enjoyment of that good cannot readily be denied to anybody, regardless of whether he or she has contributed to its purchase, upkeep, or maintenance. Goods with non-rival property rights may suffer from insufficient provision, springing from the free rider problem, the widespread occurrence of individuals enjoying a good or service to some extent in excess of what he or she has paid. The free-rider problem is the economically logical, if socially undesirable, result for non-rival goods, also called public goods. This problem is based on the reasoning that since the good or service will be provided anyway, whether one has paid or not, one may as well not pay and let somebody else foot the bill.

One aspect of oyster reefs - harvest rights on private leases - may be treated as non-attenuated private property. All costs and benefits, in the absence of poaching, accrue to one person or party (exclusive). Any oysters removed from the bottom are unavailable to others (rival).

Public oyster reefs as seed and market oyster grounds are non-exclusive or common property resources. Thus, without careful monitoring, they may be susceptible to over-use.

All oyster reefs, public and private, in their capacity as recreational fishing grounds, are non-exclusive property. In the absence of over-crowding, they may be viewed as non-rival. This makes oyster reefs vulnerable to over-exploitation or under-investment.

Correcting Incomplete Property Rights: Policy and Valuation

Without corrective measures, common property resources and public goods will suffer from inefficient provision – including depletion or exhaustion. Policy, including the drafting of protective laws or the creation of institutional arrangements, is a common element in the process of ameliorating problems caused by incomplete property rights. Estimating the value of resources is frequently an important element in the formation and institution of efforts to prevent the twin problems of under-provision and over-exploitation.

One solution may be to create private property rights, such as those available through Louisiana's leasing of oyster grounds to private lease-holders (Keithly, Roberts, and Brannan, 1992.) Another solution may be to restrict access to a limited number of people, such as the Texas shrimp license buy-back program. Fishing creel limits and hunting bag limits are other policy tools designed to reduce access to or take of a common property resource.

Another common solution is to assign the provision, protection, and maintenance of public goods or common property resources to some government body funded by taxes, license fees, or user fees.

Non-Market Valuation Techniques

Although it is not clear from observing market activities alone, public goods and common property resources frequently do possess value. To estimate these values, economists rely upon a variety of non-market valuation techniques. The most commonly employed methods fall into two categories: revealed preference and stated preference techniques.

Revealed Preference Models

Revealed preference techniques estimate the value of a good using market data, consumer characteristics, activities, and purchases, and the prices of goods and services related to the commodity in question. The three most common revealed preference methods are the hedonic price method, the travel cost method, and the random utility method.

The hedonic price method estimates the value of an environmental commodity (or characteristic) by examining property values and characteristics of houses or other real estate in its proximity. This method may be used, for example, to estimate the value of a scenic lake by observing prices of houses located along its shores.

The travel cost method estimates the value of a location or activity based on the costs incurred by individuals traveling to enjoy the site or activity. The value of a fishery, for example, may be estimated by compiling travel expenses and various characteristics of the participating anglers.

The random utility model, a derivative of the travel cost method, uses data on individual visits to a site and characteristics of the site to estimate the satisfaction derived therefrom. Changes in value are measured as site characteristics vary (Schwabe and Schuhmann, 2002). Random utility models may be used to measure the value of improving the quality of a site, such as cleaning contaminated water or preventing the loss of fish (Parson and Hauber, 1998).

The site-choice model is a derivative of the random utility model. It incorporates the results of random utility model estimates into a separate model of individual choice, participation, or selection (Montgomery and Needelman, 1997; Jakus, Dadakas, and Fly, 1998).

Stated Preference Methods

Stated preference methods are based on valuation responses provided directly from individual respondents. The most common is the contingent valuation method which measures value as a function of the willingness to pay for a commodity or willingness to accept compensation for its loss. The contingent valuation method centers around questions eliciting how much a respondent would be willing to pay (or accept compensation)[1] for a good. The elicitation must include a description of a realistic or plausible scenario for the maintenance of the evaluated good that is comprehensible to the respondent.

A comprehensive inventory of recent contingent valuation studies (which now number in the thousands) compiled by Cameron (2001), can be seen at www.sscnet.ucla.edu/ssc/labs/cameron/nrs98/nrcvr.htm. Diamond and Hausman (1994) and Hanemann (1994) present debates regarding the validity of the contingent valuation method, a technique that is not universally accepted in the economics profession. In 1993, the National Oceanic and Atmospheric Administration convened a panel of experts (the N.O.A.A. "Blue Ribbon Panel"), including two Nobel Prize-winning economists, to assess the validity of contingent valuation for damaged resource assessment. While qualifying their findings with a number of caveats, the Panel generally concluded that contingent valuation, if properly used, could provide realistic estimates of value associated with non-market goods. Although the potential of the technique is limited, there are frequently no other methods available to measure the value of non-market goods.

The willingness to pay question is generally framed in either the open-ended or dichotomous choice format. The open-ended format asks the respondent how much he or she would be willing to pay without inclusion of a specific dollar amount. The respondent provides his or her own dollar value when asked for willingness to pay.

[1] For a variety of theoretical and conceptual reasons, willingness to accept compensation measures are seldom seen in the evaluation literature. A Blue Ribbon panel compiled by the National Oceanographic and Atmospheric Administration to evaluate the contingent valuation method strongly discouraged the use of willingness to accept compensation measure (Arrow, *et al*., 1993).

Example: Open-Ended Contingent Valuation Method Format

From Milon and Thunberg, 1994, p. A-28:
"Please write in the space below the maximum amount of money you would be willing to pay for [a] special Red Fish stamp. If for any reason you would not be willing to pay for [a] special Red Fish stamp, please write in a 0.

______ (Write in a $ amount or 0.)

The dichotomous choice method does not ask the respondent to provide a dollar amount but rather asks whether he or she would be willing to pay a pre-set amount for the good. The pre-set dollar amount varies across respondents. The respondent's "yes or no" response to this question is then combined with socioeconomic characteristics and other parameters in a statistical model designed to estimate the value of the good.

Example: Dichotomous Choice Contingent Valuation Method Format

From McConnell and Strand, 1992, p. 54:
"If your cost for this day had increased by a [randomly selected amount of $5, $15, $30, $50, $75, $100, $150, $200] would you still have gone fishing?"

Each of these methods has problems with implementation and analysis, with some disposition towards bias and inaccuracy. Nevertheless, recent practice, following the recommendations of the N.O.A.A. Blue Ribbon Panel, has favored the dichotomous choice format (Arrow, *at el.*,, 1993; Hannemann and Kanninen, 1999). This method, its advocates say, is more familiar to respondents, being similar to market transactions in which persons decide whether to buy an item based on a pre-set price. (Rarely are consumers asked how much they are willing to pay for a good. Instead, the person demonstrates his or her value for the item when he or she decides to purchase it, upon reading its price tag.) This format is easier for the respondent to answer but requires a large sample for statistical inference. Critics say it is prone to generate positive responses to values that exceed the respondents' true willingness to pay and thus generate inaccurately high value estimates. Advocates dispute this tendency towards over-estimation (Huang and Smith, 1998).

Economic Research: Gulf Recreational Fishing

Haab, Whitehead, and McConnell (2001) employed contingent valuation and random utility models to gauge willingness to pay for access to marine recreational fishing in various coastal states. Value of site access to pelagic species[2] in North Carolina varied widely from a low of $0.24 in March and April to $73.67 in September and October. Willingness to pay for access to red drum ranged from $61.58 in March and April to $90.73 in July and August. Employing a random utility model, they estimated the value of access per trip in the Gulf of Mexico across states as $82.22. The value of access per trip in Louisiana alone was $11.68.

Whitehead and Haab (2001) employed an open-ended contingent valuation study of willingness to pay for a permit to avoid tighter bag limits for king mackerel, red snapper, and gag in the southeastern United States. The annual value of avoiding tighter bag limits for king mackerel ranged from $1.54 in Louisiana to $4.79 on the Florida Atlantic Coast. The annual value of avoiding a one-fish drop in bag limits for red snapper ranged from $0.44 in Alabama to $1.22 in Louisiana to $1.90 on the Florida Gulf Coast.

[2] Pelagic species include bluefish, cerro, Spanish mackerel, cobia, dolphin, and little tunny.

Milon and Thunberg (1994), in a survey of Florida residents, employed the contingent valuation method with an open-ended willingness to pay format to estimate the value of a special permit to obtain more permissive bag limits for six fishes. Average willingness to pay for a looser bag limit was $0.03 for mullet, $0.11 for pompano, $0.20 for sheepshead, $0.68 for king mackerel, and $1.94 for red drum.

McConnell and Strand (1994) estimated the value of access and the value of a change in the quality of fishing in coastal states stretching from Long Island to Dade County, Florida. Using the contingent valuation method to determine the willingness to sell (or willingness to accept compensation for the surrender of) fishing access, they estimated the average value (willingness to sell) of fishing rights in Georgia ($688) and the Atlantic coast of Florida ($658). They estimated the aggregate annual value of access to saltwater angling as $77.1 million in Georgia and $1.21 billion on Florida's Atlantic coast. (Estimates are quoted in 1988 dollars.)

The average value of two-month access rights to saltwater fishing (based on contingent valuation willingness to sell) in Florida ranged from a low of $157 in winter to $256 in summer. In Georgia, the average value of two-month access to fishing peaked at $240 in summer and troughed at $105 in late autumn.

Using the contingent valuation method in a study of willingness to pay to increase the catch rate by one fish per fishing trip, McConnell and Strand (1994) estimated the value of an extra one-half fish per day on the Florida Atlantic coast was $24.60. The seasonal aggregate value of an increase in the saltwater daily catch rate in Florida ranged from $11.7 million for September and October to $35.6 million for January and February.

Chapter 3-5. Data and Survey Methods

Introduction

This chapter presents descriptive statistics drawn from the National Marine Fisheries Service's Marine Recreational Fishing Statistical (M.R.F.S.) Survey. A sample of Louisiana resident Intercept Survey respondents was drawn for participation in a telephone survey that would elicit more information, including willingness to pay, from individual respondents. Information within the telephone survey allowed the division of the sample into subsamples of users and non-users of oyster reefs for recreational fishing.

Evidence of statistical differences between users and non-users is noted. Differences exist in education, income, parish of intercept, and a variety of angling practices. Users are then included in a contingent valuation survey to estimate the average willingness to pay to maintain fishing access over oyster reefs in Louisiana.

National Marine Fisheries Service Intercept Survey Methods

Data used in this research were provided by respondents to the M.R.F.S. Survey and a related survey conducted by the Louisiana Department of Wildlife and Fisheries. The M.R.F.S. Survey consisted of personal interviews of anglers who were intercepted at the dock or along shore and were identified as having participated in recreational fishery activities. The survey was administered every two months from June, 2000 to May, 2001. One individual fisherman could thus be interviewed more than once.

Geographical Distribution of Intercepted Anglers

The M.R.F.S. Survey sample was examined to determine the geographical distribution of anglers in Louisiana and users of oyster reefs. Almost eighty-eight percent

(87.78%) of all intercepted anglers were residents of Louisiana. The participation rates by residents and non-residents in Louisiana were similar to those across the United States as a whole. Nationally, 11 – 12 percent of all fishing days in the United States take place out-of-state, that is, in states other than the individual anglers' home states (Ditton, Holland, and Anderson, 2002).

Following Louisiana, the most common states of residence (Figure 3-7) among the intercepted anglers were neighboring Mississippi (3.01%) and Texas (2.72%). As a general trend, more distant states were represented by smaller numbers of intercepted anglers. Arkansas and Oklahoma combined were the states of residence for 0.49% of the respondents. On a regional basis (Figure 3-8) the Southeast was the residence of 3.9% of the respondents, the Northeast for 0.4 %, the Midwest 0.9%, and the West for 0.4%.

Among the questions included in the M.R.F.S. Survey was an inquiry regarding the utilization of oyster reefs by recreational anglers: "Did you fish over an oyster reef on this trip?" One thousand two hundred one (22.72%) had fished over an oyster reef on the day of the survey intercept; 3,280 (62.05%) had not; and 805 (15.23%) were uncertain. Three hundred thirty of the intercepted anglers did not respond to the question. Since the N.M.F.S. Survey is a random sample of fishing days, these findings indicate that 22.72% of saltwater fishing days in Louisiana were performed at least in part above oyster reefs.

There were some statistically significant differences ($X^2_{(df = 14)} = 60.32$) in utilization of oyster reefs among residents of different states and regions (Figure 3-8). The percentage of respondents who fished over an oyster reef on the day of interception was not statistically different among residents of various regions, except among residents in the Southeast who were less likely to fish over oyster reefs (14.75%) than residents in

Figure 3-7. State of Residence for M.R.F.S. Survey Respondents (by Number of Intercepted Anglers)

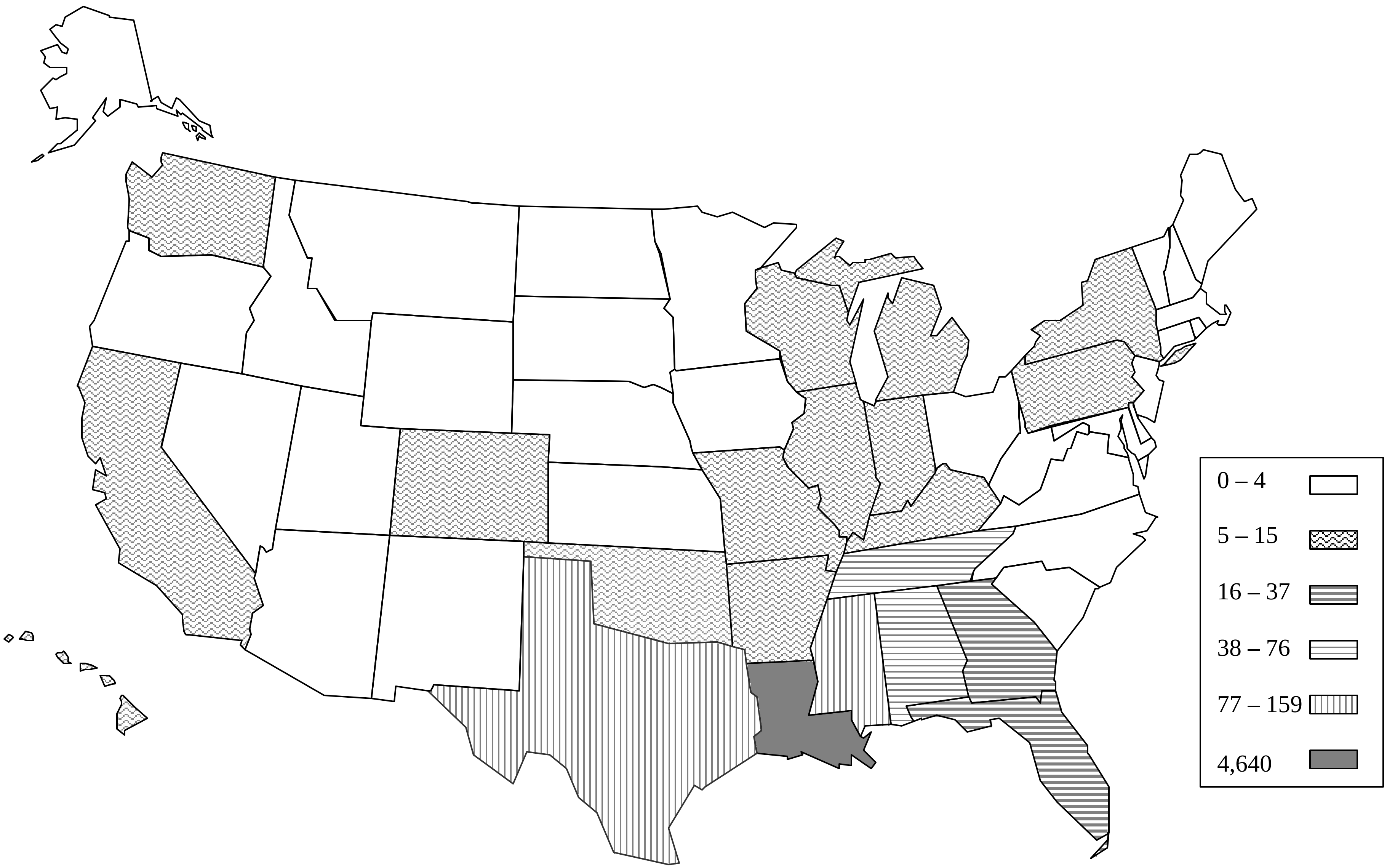


Figure 3-8. Regional Divisions of the United States

other states or regions. Mississippians were statistically less likely to have not fished over an oyster reef on the day of interception (59.2%) and more likely to provide an "Uncertain" answer (25.8%). Among Louisiana residents, 23.3% fished over an oyster reef on the day of interception, 63.5% did not, and 14.1% were uncertain.

The percentage of Louisianans who did not know if he or she had fished over an oyster reef on the day of interception (14.1%) was significantly less than the portion of residents from other states or regions who provided an uncertain answer (23.6% of all non-Louisiana residents combined).

The rate of utilization of Louisiana oyster reefs may be compared to previous estimates of utilization of selected reefs in the Gulf of Mexico. In Mobile, Alabama, 41.1% of saltwater fishing days are over artificial reefs. In Pensacola, Florida and Biloxi, Mississippi, 36% and 39.1%, respectively, of saltwater angling days take place over artificial reefs (Posadas, *et al.*, 1991). The relatively small portion of fishing days over oyster reefs in Louisiana, compared to the portion over artificial reefs by anglers from nearby cities, may be a result of the relatively expansive geographical area in the Louisiana study. Because this sample was drawn along an entire state's coast rather than one city, respondents are presented with more substitute angling opportunities than those in the Posadas, *et al.*, (1991) study. Anglers were thus more likely to disperse their activities among more numerous locations.

Louisiana Department of Wildlife and Fisheries Telephone Survey

The research presented in this report was based on a follow-up telephone interview conducted by the Louisiana Department of Wildlife and Fisheries of 2,336 persons who had earlier responded to the M.R.F.S. Survey. All residents of states other than Louisiana were excluded and the sample was combed to eliminate duplicate telephone surveys to the same individual. The telephone survey was administered by employees in the Socioeconomic Research and Development Section of the Louisiana Department of Wildlife and Fisheries from June, 2000 to August, 2001. The Louisiana residents who participated in the NMFS Survey were divided into two groups: those who fished over an oyster reef on the day of intercept and those who did not. Three attempts were made to contact all participants at various times of day. To eliminate bias, a limited number of interviewers were used, and they were instructed to follow closely a specifically worded script. The survey was pre-tested on 50 people prior to the implementation of the telephone survey.

Included in the telephone survey sample were 720 respondents who said they had fished over an oyster reef on the day of the personal intercept survey and 1,616 respondents who said they had not fished over an oyster reef on the day of intercept. Among those who said they had fished over an oyster reef on the day of intercept, 243 (33.8%) responded. Among the others, 548 (33.9%) responded. Over all, 791 of the 2,336 telephone interviews responded to the telephone survey for a response rate of 33.9 percent. In general, the relatively large non-response rate reflected an inability to contact the appropriate person rather than refusal to respond to the telephone survey.

These two sub-samples were examined and reconfigured to define a user group ("reef anglers") and a non-user group. The user group included all respondents who had fished over an oyster reef within the previous year, not just on the day of intercept. Thus the user group was a combination of those who had fished over an oyster reef on the day of intercept plus those who had not fished over an oyster reef on the day of intercept but did admit to fishing over an oyster reef within the past year as part of the telephone interview.

The respondents who said “no” or “I don’t know” when asked if they had not fished over an oyster reef on the day of intercept were asked in the telephone interview if they had fished over an oyster reef within the previous twelve months. Of this group, 203 had not fished over an oyster reef in the past year and 345 had. The 203 who had not fished over an oyster reef in the past year were labeled the “non-user” group.

All 345 anglers who did not fish over an oyster reef on the day of intercept but had fished over an oyster reef in the past year were combined with 211 respondents who had fished over an oyster reef on the day of the intercept in a category labeled “oyster reef user group” or “reef anglers.” (Thirty-two respondents who had fished over an oyster reef on the day of intercept were excluded for providing an inconsistent response in a telephone interview question, reporting that they had fished zero percent of the time over an oyster reef in the previous year.)

Among reef users (Table 3-7), 211 had fished over an oyster reef on the day of intercept. Three hundred thirty-three had not fished over an oyster reef on the day of

Table 3-7. Delineation of Oyster Reef Users and Non-Users

		MRFSS Survey					
L.D.W.F.	Did You Fish Over an Oyster Reef in the Past Year?		Did You Fish over an Oyster Reef Today?				
			Yes	No	I Do Not Know	TOTAL	
		Yes	211*	333	12	556	USERS
		No	----	192	11	203	NON-USERS
		TOTAL	211	525	23	759	
		* 32 Positive respondents were eliminated for supplying inconsistent answers.					

intercept. Twelve respondents were uncertain about fishing over an oyster reef on the day of intercept but said they had fished over an oyster reef within the previous year. The total for active oyster reef anglers was 556. Responses from these 556 oyster reef users were used to develop an estimate of indirect consumptive use value for access to fishing over an oyster reef.

Non-users were excluded from this estimation of the value of recreational fishing over oyster reefs. Because they are not actively using the resource, it is likely that the value obtained from non-users would be an option value or existence value.

Geographical Distribution within the State: Place of Intercept and Residence

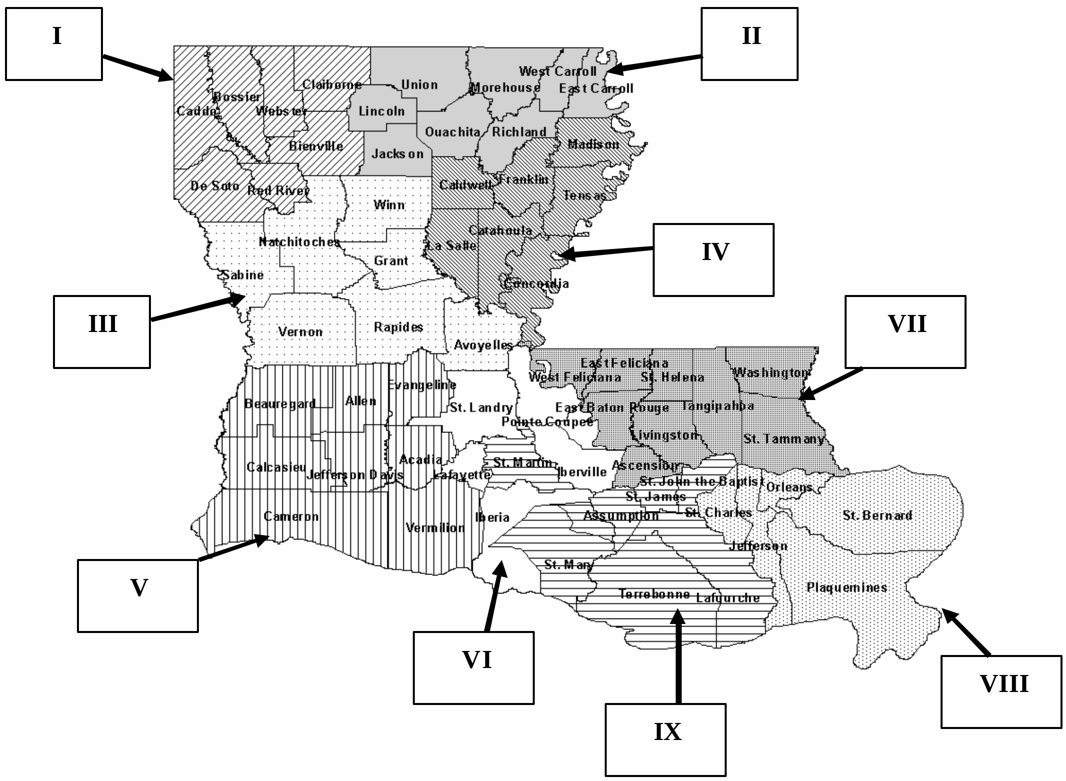
Two variables collected in the N.M.F.S. Survey, Parish (or County) of Intercept and Parish (or County) of Residence may be used to examine where respondents fished and where they live.

Respondents resided in 34 of Louisiana's 64 parishes. To present geographical distribution in a more comprehensible manner (and one less likely to generate distorting statistical problems), parishes were combined into nine separate regions based on the Louisiana Department of Wildlife and Fisheries Enforcement Division's Regions (Figure 3-9). These regions are dispersed throughout the state and separate the more heavily populated southeastern regions into distinct categories that provide an opportunity for detailed statistical analysis.

Place of Intercept

N.M.F.S. Survey intercepts were made in 13 Louisiana parishes along the Gulf of Mexico or Lake Pontchartrain coasts in Regions V – IX. The parishes with the most intercepts of active oyster reef anglers were Plaquemines Parish (158), Jefferson Parish

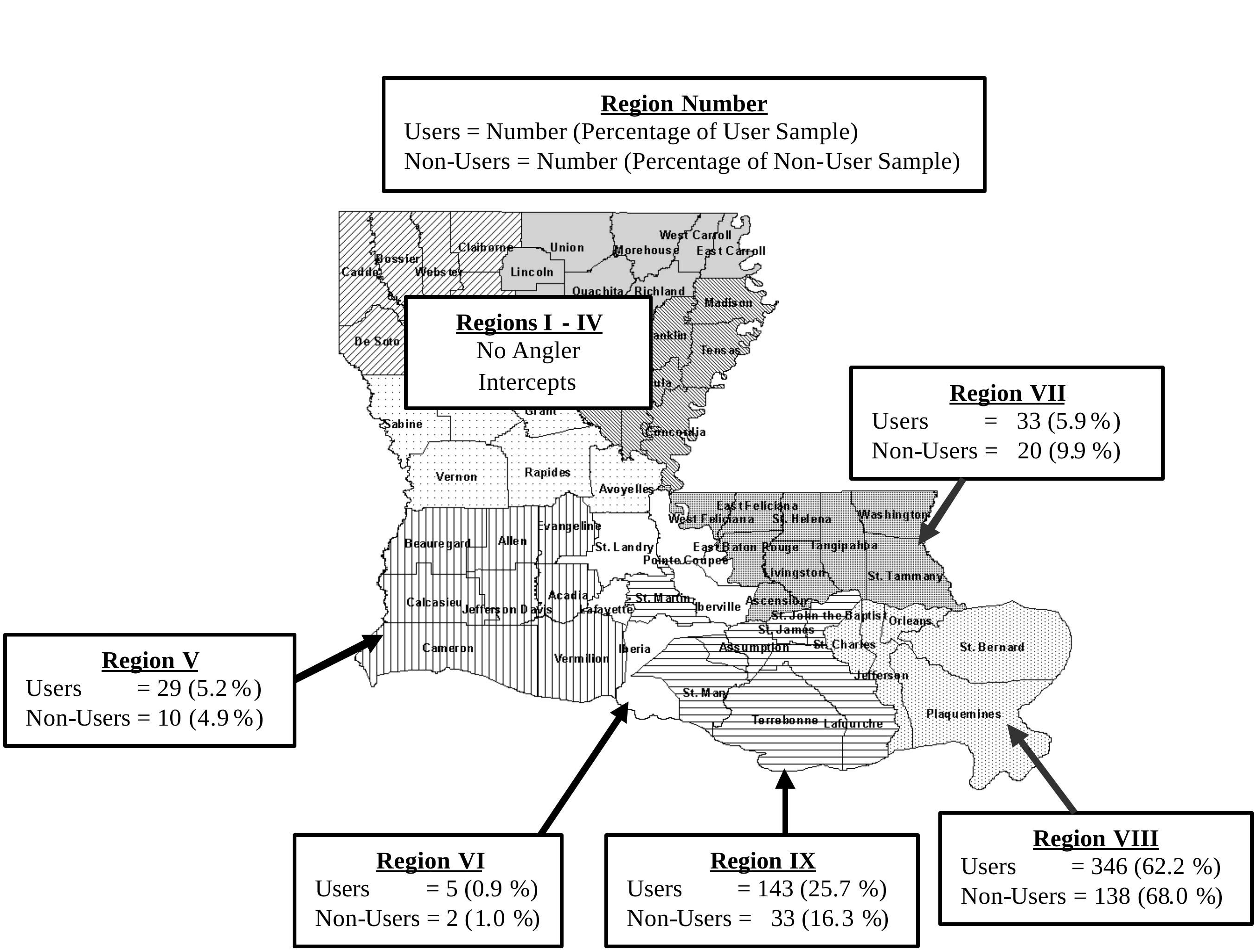
Figure 3-9. Louisiana Department of Wildlife and Fisheries Enforcement Division Regions



(114), Terrebonne Parish (90), St. Bernard Parish (56), and Lafourche Parish (28), representing 80.2 percent of all reef users. These five parishes are relatively close and accessible to the most populated areas of the state. They cover a large section of the coast and are known as productive angling areas. They also contain the most productive oyster grounds. Three of these parishes (Plaquemines, St. Bernard, and Lafourche) produced over three-quarters of the commercial oyster harvest in 2000.

To accomplish an examination of the rate of oyster reef utilization by region, intercepted anglers were divided into five groups, based on the Enforcement Division's Regions V – IX, each of which contained at least one coastal parish (Figure 3-10).

Figure 3-10. Region of Intercept of Intercepted Anglers by Wildlife Enforcement Division Region



Region VI, with only one coastal parish, Iberia, reported the smallest number of intercepts. The two coastal parishes in Region V include a broad expanse of coast, but are relatively lightly populated areas with shallow shores that are not as popular as fishing areas in the eastern portion of the state. Region VII is a smaller area than Region V, yet contains roughly the same number of intercepts. This more densely populated area borders Lake Pontchartrain and also affords access to the Gulf of Mexico. The vast majority of angler intercepts, almost 88 percent, occurred in Regions VIII and IX, which cover the rich angling zones stretching from East Cote Blanche and Atchafalaya Bays on the west to the Mississippi state line on the east.

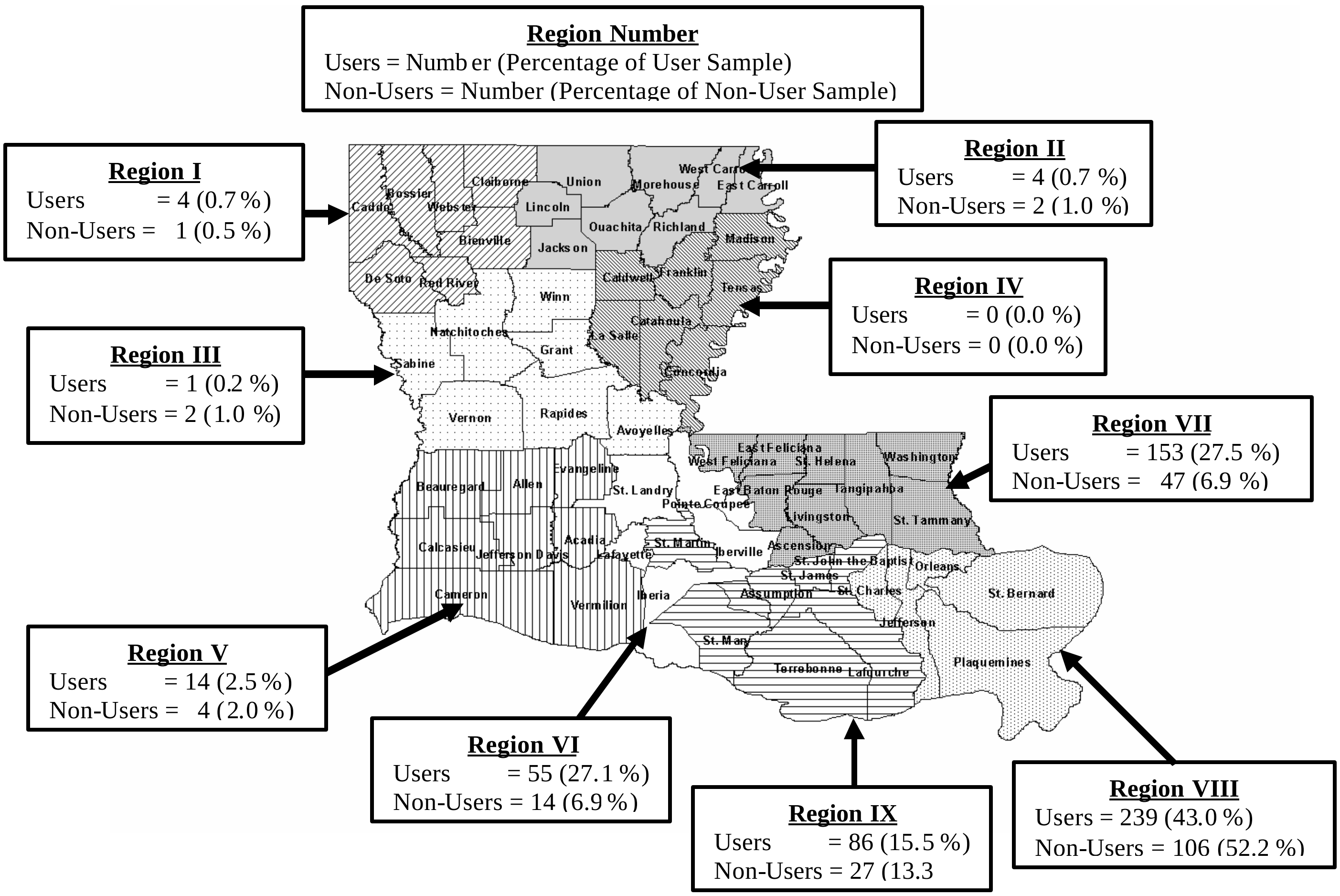
The parish of intercept for users differed significantly from the interception parish for non-users at the a = 0.05 significance level ($X^2_{(df = 4)} = 9.88$). A larger portion of non-users (9.9 percent) than users (5.9 percent) were intercepted in Region VII. A larger share of users (25.7 percent) than non-users were intercepted in south central Region IX, which includes oyster-rich areas off Terrebonne and Lafourche Parishes.

Anglers' Parish of Residence

All oyster reef users in this sample were residents of Louisiana and most lived in parishes that are close to the most productive oyster grounds (Figure 3-11). Jefferson, Orleans, and St. Tammany parishes together claimed 253 (45.5 percent) of all active oyster reef anglers. East Baton Rouge parish was the residence of 45 anglers (8.1 percent). One-hundred five oyster reef anglers (18.9 percent) lived in the four parishes with the largest commercial oyster harvests: Plaquemines, Terrebonne, Lafourche, and St. Bernard.

All together, approximately thirty-seven percent (208) of the reef users resided in the south-central and southeastern Regions VI and VII which includes the cities of Lafayette and Baton Rouge and the heavily populated New Orleans suburbs in St. Tammany parish. Regions VIII and IX cover the southeastern corner of the state, including New Orleans, and were the places of residence for 58.5 percent of the user sample. The parishes in Regions VI through IX are the most densely populated in the state and together account for 64.9 percent of the state's population.

Figure 3-11. Region of Residence of Intercepted Anglers by Wildlife Enforcement Division Region



Region V in the southwestern corner of the state was the region of residence of 14 (2.5%) of the reef anglers. Region V contains one large city, Lake Charles, but is otherwise relatively lightly populated. Compared to the southeastern quadrant of the state, many portions of the coast in southwestern Louisiana are not readily accessible. The relatively small quantity of oysters in Region V may be another factor explaining the small portion of reef users. In 2003, this region contained only 21 private leases with

5,717 acres of water bottoms (all in Vermilion Parish.) There are two public tonging areas in this region, Calcasieu Lake and Sabine Lake, but relatively minor production.

Only 9 oyster reef anglers resided in the parishes situated in the northern, non-coastal Regions I through III. No intercepted anglers resided in Region IV.

Combining parishes of residence of users and non-users into the appropriate Enforcement Division regions allows a statistical comparison of geographical origin. Dropping Region IV from both samples, neither of which contained an observation from that area, reduces the number of geographical categories to six. A Chi-square test ($X^2_{(df = 5)} = 8.677$) revealed no significant difference between users and non-users based on this criteria.[1]

Mode of Fishing, Gear, and Area

The most common mode of fishing on the day of intercept among reef users was a private or rented boat (86.3%). Charter boats were used by 5.2 percent. An equal share (5.2%) fished from a pier, dock, jetty, bridge, or other man-made structure. Approximately three percent of active oyster reef fishermen fished from shore on the day of intercept.

Oyster reef users and non-users demonstrated a difference in mode of fishing on the day of intercept ($X^2_{(df = 6)} = 54.59$). Oyster reef users were more likely to fish from a private or rented boat (86.3 percent) than non-users (68.0 percent) but less likely to have fished from a pier, jetty, bridge, or other man-made structure (5.2 percent for users vs. 19.7 percent for non-users).

[1] In an effort to reduce the distortion of the Chi-square parameter caused by multiple categories with a small number of responses, Regions I – III were combined into one category for statistical analysis. With this reduction of degrees of freedom from eight to five, a Chi-squared test, $X^2_{(df=5)} = 6.563$, also revealed no significant difference in parish of residence between users and non-users.

There is apparently little diversity of gear used by reef users. Virtually all users (98.9%) fished with hook and line on the day of intercept. This is not significantly different from the gear used by non-users.

The large majority of reef anglers (88.7%) reported fishing in a bay on the day of intercept. An even larger portion of non-users reported fishing in a bay or estuary on the day of intercept, but the difference was not statistically significant.

Boat Ownership

Boat ownership was widespread among active reef anglers. Over three-quarters (77.5%) said that somebody in his or her household owned a boat used in marine recreational fishing. No information regarding the size or value of boats was collected.

The portion of non-users reporting the existence of a boat owner in his or her household (63.1 percent) was significantly less than the boat ownership rate among users ($X^2_{(df\ =\ 2)}$ = 16.49). This seems to mimic the previously noted differences in mode of fishing on the day of intercept.

Party Size

Few reef anglers fished alone. On the day of intercept, 11.39 percent had only one person in the boating party (the survey respondent.) Nearly half (48.5%) included two in his or her boating party and approximately one-quarter (27.7%) reported three (Table 3-8). Less than two percent were made up of four or more persons. The average number of people in a boating party was 2.4. This is not significantly different from the average number of persons in the non-users' boating parties.

Table 3-8. Numbers of People in Boating Parties

	Users (N = 509)		Non-Users (N = 149)	
	Number	**Percentage**	**Number**	**Percentage**
1 Person	58	11.39	13	8.72
2 Persons	247	48.53	79	53.02
3 Persons	141	27.70	41	27.52
4 Persons	54	10.61	14	9.40
5 Persons	8	2.88	2	1.34
6 Persons	1	0.20	0	0.00
	Frequency Missing = 47		Frequency Missing = 54	

Time Spent Fishing

Among reef anglers, the average and median length of time spent fishing with gear in the water on the day of interception was four hours (Table 3-9). Less than one-sixth (90) fished for two hours. Another one-fifth (105) fished for two to three hours. Over forty percent (247) spent three to five hours fishing on the day of intercept. The average fishing trip duration among non-users was not significantly different from that of the average reef user.

Most anglers who took part in the M.R.F.S.S. were intercepted returning to shore at midday. Nearly half (44.96%) were interviewed between 12:00 noon and 1:59 p.m.; one-quarter were interviewed between 10:00 a.m. and 11:59 noon.

Table 3-9. Hours Spent Fishing on Day of Intercept

	Users (N = 556)		Non-Users (N = 203)	
	Number	**Percentage**	**Number**	**Percentage**
One hour or less	25	4.50	16	7.88
1:01 to 2 hours	65	11.69	23	11.33
2:01 to 3 hours	105	18.88	36	17.73
3:01 to 4 hours	132	23.74	45	22.17
4:01 to 5 hours	115	20.68	35	17.24
5:01 to 6 hours	73	13.13	27	13.30
6:01 to 7 hours	20	3.60	15	7.39
7:01 to 8 hours	15	2.70	4	1.97
More than 8:01 hours	6	1.08	2	0.99
	Average = 4.07		**Average = 4.02**	

Number of Days Fished

Two questions on the M.R.F.S. Survey were designed to measure angling avidity. These questions asked the number of days, excluding the day of the intercept, fished during the previous two months and the previous year. For the user sample, the average number of days spent fishing for the past two months (Table 3-10) was 5.03 days. Over one- sixth of the reef anglers (96) had not fished at all within the two months prior to the M.R.F.S. Survey. Three-quarters (421) fished one to fifteen days. The number of days spent saltwater fishing in the last two months among reef users and non-users (4.50) was not significantly different.

Nearly one-half of the user sample (275) fished from one to twenty days in the year prior to the M.R.F.S. Survey. Nearly one-quarter (130) had fished from 21 to 40 days in the previous year (Table 3-11). The average number of days spent fishing by reef users over the past 12 months was 31.71 days. This was higher, but not significantly so, than the average number of saltwater fishing days by non-users in this sample (25.36).

The average number of saltwater fishing days taken by users in this sample (as well as that among non-users) exceeds the U.S. Fish and Wildlife Service (2002) estimate of 11 days of saltwater fishing per Louisiana resident angler in 2001.

Table 3-10. Number of Days of Saltwater Fishing, in Addition to the Day of Intercept, in the Previous Two Months

	Users (N = 556)		**Non-Users (N = 203)**	
	Number	**Percentage**	**Number**	**Percentage**
Zero Days	96	17.27	58	28.57
1 to 15 Days	421	75.72	134	66.01
16 to 30 Days	36	6.47	5	0.899
31 to 45 Days	3	0.54	4	0.718
More than 45 Days	0	0.00	1	0.49
	Average = 5.03		**Average = 4.50**	

Table 3-11. Number of Days of Saltwater Fishing, in Addition to the Day of Intercept, in the Previous Twelve Months

	Users (N = 556)		Non-Users (N = 203)	
	Number	Percentage	Number	Percentage
Zero Days	21	3.78	21	10.34
1 to 10 Days	172	30.94	75	36.95
11 to 20 Days	103	18.53	39	19.21
21 to 30 Days	93	16.73	23	11.33
31 to 40 Days	37	6.65	7	3.45
41 to 50 Days	44	7.91	12	5.91
51 to 60 Days	26	4.68	9	4.43
61 to 70 Days	31	5.58	1	0.005
71 to 80 Days	8	1.43	2	0.99
81 to 90 Days	2	3.60	1	0.005
91 to 100 Days	16	2.88	5	2.46
More than 100 Days	29	5.22	7	3.45
	Average = 31.71		**Average = 25.36**	

Years of Recreational Angling Experience

The average oyster reef user in this sample had fished for 27.08 years (Table 3-12). There is no statistically significant difference between the average respondent's number of years fishing in the user and non-user samples.

Table 3-12. Years Fished by Intercepted Anglers

	Users (N = 556)		Non-Users (N = 203)	
	Number	Percentage	Number	Percentage
Zero Years	2	0.36	2	0.99
1 – 10 Years	104	18.71	52	25.62
11 – 20 Years	124	22.30	40	19.70
21 – 30 Years	128	23.02	44	21.67
31 – 40 Years	100	17.99	28	13.79
41 – 50 Years	74	13.31	24	11.82
51 – 60 Years	17	3.06	10	4.93
61 – 70 Years	4	0.72	2	0.99
71 – 80 Years	0	0.00	0	0.00
81 – 90 Years	0	0.00	0	0.00
90 – 100 Years	3	0.54	3	1.48
	Average = 27.08		**Average = 25.87**	

Species of Fish Targeted

The most common primary targeted species (Table 3-13) was spotted seatrout (*Cynoscoin nebulosus*), sought by 41.19 % of reef anglers. The second most common primary target species was red drum (*Sciaenops ocellatus*), pursued by 36.51%. One-fifth (19.42%) of the reef anglers did not target any particular species on the day of intercept.

Kelso, Monzyk, and Rutherford (1999) reported slightly different results in their survey of saltwater anglers in Louisiana. In their sample, 24 percent targeted no particular species. Spotted seatrout was the first choice of 37 percent of saltwater anglers. Red drum were pursued by 29.6 percent of their sample.

Felder and Leahy (1998) found that 16.8% of Louisiana anglers in 1996 fished for "nothing in particular." Anglers fishing for no particular species tended to fish fewer days (8.2) on average, than Louisiana anglers as a whole who spent, on average (22.7 days). Only 6.08% of all angling days in the Felder and Leahy study targeted "nothing in particular."

Non-users demonstrated a different pattern in the targeting of primary species of fish ($X^2_{(df = 3)} = 17.06$). Although the portion of each group targeting spotted seatrout and

Table 3-13. Primary Targeted Species on Day of Intercept

	Users (N = 556)		**Non-Users (N = 203)**	
	Number	**Percentage**	**Number**	**Percentage**
Speckled Sea Trout	229	41.19	65	32.02
Red Drum	203	36.51	66	32.51
All Other Species	16	2.88	4	1.97
Nothing in Particular	108	19.42	68	33.50
Marine Recreational Fishery Statistical Survey data				

red drum was not significantly different, a statistically larger portion of non-users (33.5 percent) than users (19.42 percent) did not target any particular species on the day of intercept

Many anglers focused on one species and did not identify a secondary target species (Table 3-14). Nearly two-thirds of reef users (64.14%) and non-users (65.52 %) did not report a secondary target species. Among those active oyster reef anglers who did name a secondary target species, the most common was red drum (50.3%). The most common primary target species, spotted seatrout, was the second-most common secondary target species (40.2%). There was no significant difference between users and non-users in the identification of secondary targeted species.

Education

The typical oyster reef user had more formal education than most Louisianans. The portion of reef users with at least a high school diploma, 97.65 percent, is larger than the portion of the state population, eighteen and older, that graduated high school (79.6 percent). The user sample also contains a higher portion of people holding a bachelor's degree or graduate education (41.72 percent) than the state population (19.7 percent) (U.S. Census Bureau, 2001).

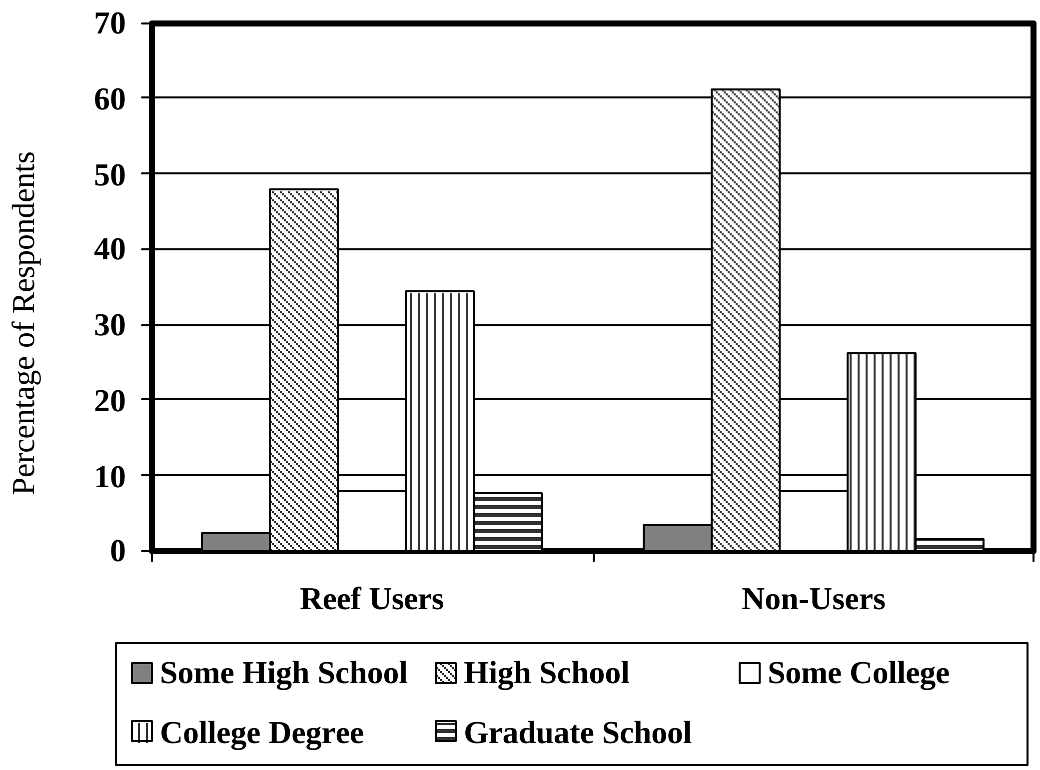
Table 3-14. Secondary Targeted Species on Day of Intercept

	Users (N = 556)		**Non-Users (N = 203)**	
	Number	**Percentage**	**Number**	**Percentage**
Speckled Sea Trout	80	14.41	30	14.78
Red Drum	100	18.02	38	18.72
All Other Species	19	3.42	2	0.99
Nothing in Particular	356	64.14	133	65.52
Marine Recreational Fishery Statistical Survey data				

Reef users tend to have more formal education than non-users (Figure 3-12) in this sample ($X^2_{(df = 5)} = 18.16$). A smaller portion of oyster reef users (47.83%) than non-users (61.08%) had a high school diploma as a terminal degree, and a larger portion of users (34.3%) than non-users (26.11%) had a college education.

The education levels among Louisiana oyster reef users are similar to that of U.S. saltwater anglers. In 1996, over half of U.S. saltwater anglers had at least some college education (Felder and Leahy, 1998). Slightly less than half of oyster reef anglers (49.63 percent) – but only 35.47 percent of non-users - had at least some college education.

Figure 3-12. Formal Educational Attainment

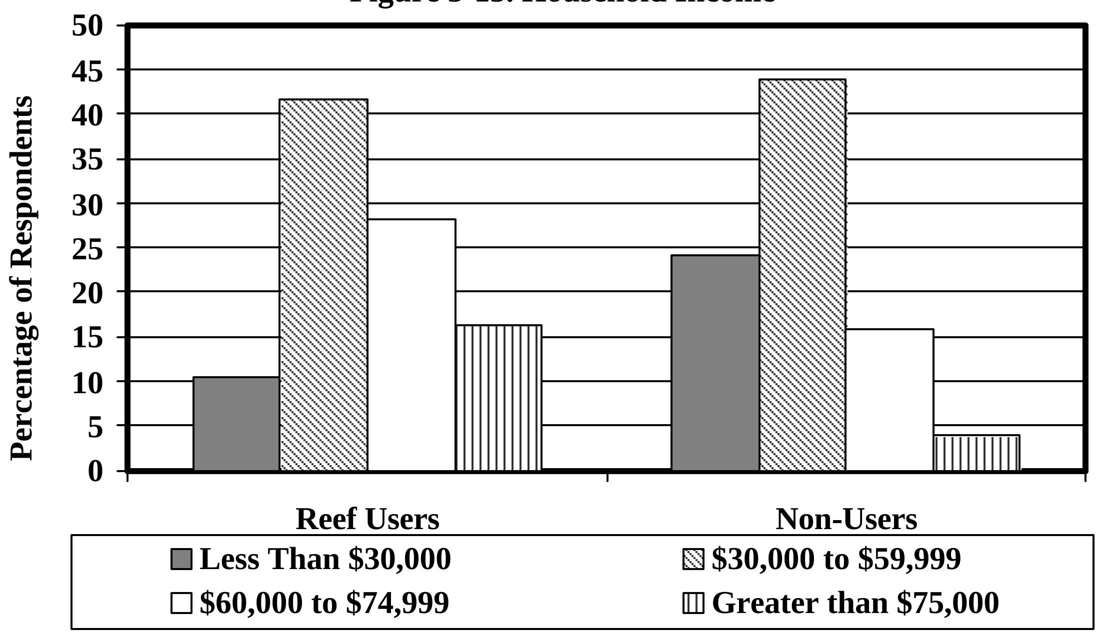


Income

Of those responding to the survey question regarding household income, a plurality of reef users (41.70 %) had an annual household income between $30,000 and $59,999 (Figure 3-13). Roughly one-quarter (28.16 %) had an income between $60,000 and $74,999 per year and one-sixth (16.43%) had household income over $75,000. The average household income among Gulf of Mexico anglers in general has been reported as $52,990 (Haab, Whitehead, and McConnell, 2001).

Reef users reported significantly higher household income than non-users ($X^2_{(df = 3)}$ = 47.61). Of the non-users who responded to this question, 24.14 percent had an annual household income beneath $30,000, a range reported by only 10.6 percent of reef users. A similar portion of users (41.55 percent) and non-users (43.84 percent) fell in the $30,000 to $59,999 range. Only 19.7 percent of non-users had a household income above $60,000, compared to over 44 percent of oyster reef users.

Figure 3-13. Household Income



Reef users tend to have more household income than Louisiana residents as a whole. The median income for Louisiana in 1997 was $30,466 (U.S. Census Bureau). Only 10.47% of the reef user sample had a household income less than $30,000 per year.

Users' Rates of Utilization of Oyster Reefs

Telephone survey respondents were asked to estimate the percentage of angling time spent over oyster reefs. The average reef user spent 35.0% of angling time over oyster reefs (Table 3-15). Most reef users (56.8%) spent less than one-quarter of their angling time over oyster reefs.

By multiplying the respondents' estimated number of saltwater fishing days by the identified percentage of time spent over oyster reefs, one can estimate the number of days spent fishing over oyster reefs. Using this method, the average number of days fished over oyster reefs by reef users within the previous two months (Table 3-16) was 1.96 days. The average number of days over oyster reefs within the previous twelve months (Table 3-17) was 11.65 days.

Table 3-15. Percentage of Saltwater Angling Time Spent Over Oyster Reefs Reported by Oyster Reef Anglers

Percentage of Time	Number (N = 556)	Percentage of Respondents
1 to 10 Percent	169	30.40
11 to 20 Percent	106	19.06
21 to 30 Percent	63	11.33
31 to 40 Percent	22	3.96
41 to 50 Percent	63	11.33
51 to 60 Percent	15	2.70
61 to 70 Percent	17	3.06
71 to 80 Percent	44	7.91
81 to 90 Percent	16	2.88
91 to 100 Percent	41	7.37
	Average = 35.0 Percent	

Table 3-16. Number of Days in Previous Two Months (in Addition to Day of Intercept) Spent Over Oyster Reefs by Oyster Reef Anglers

Number of Days	Number (N = 556)	Percentage of Respondents
Zero Days	96	17.27
Less than 1 Day	240	43.17
1 to 10 Days	201	36.15
11 to 20 Days	16	2.88
21 to 30 Days	3	0.54
	Average = 1.96	

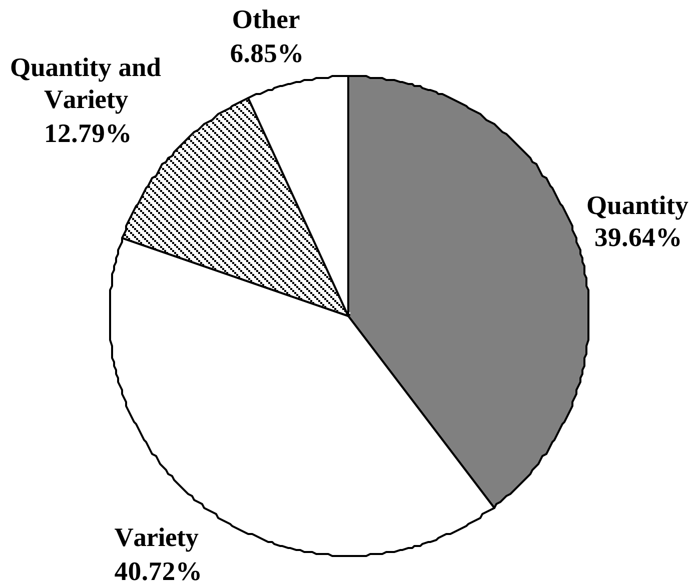
Table 3-17. Number of Days in Previous Twelve Months (in Addition to Day of Intercept) Spent over Oyster Reefs by Oyster Reef Anglers

Number of Days	Number (N = 556)	Percentage of Respondents
Zero	21	3.78
Less than 1 Day	101	18.2
1 to 10 Days	275	49.46
11 to 20 Days	73	13.13
21 to 30 Days	39	7.01
31 to 40 Days	14	2.52
41 to 50 Days	11	1.98
51 to 60 Days	8	1.44
61 to 70 Days	3	0.54
71 to 80 Days	2	0.36
81 to 90 Days	3	0.54
91 to 100 Days	1	0.18
More than 100 Days	5	0.99
	Average = 11.65	

Reasons for Fishing over Oyster Reefs

Telephone survey respondents were asked why they fished over oyster reefs (Figure 3-14). Thirty-nine percent fished over oyster reefs for the increased quantity of fish, 40.6 percent for the variety of fish present and 12.82 percent preferred reefs for both variety and quantity. A small portion (6.52 percent) cited "other" reasons for fishing over oyster reefs, such as "convenience," "accident," or the perceived presence over oyster reefs of specific targeted species of fish including trout, redfish, and flounder.

Figure 3-14. Reasons Cited for Fishing over Oyster Reefs



Economic Modeling

The value of oyster reefs as recreational fishing grounds, as measured by willingness to pay, is a function of income, fishing experience, fishing avidity, and other socioeconomic characteristics (Tables 3-19 and 3-20). Willingness to pay (WTP) was derived from the telephone survey, centered on the yes or no response to a question asking respondents if they would pay a randomly selected amount to maintain access to fishing reefs in Louisiana. Respondents who reported fishing over oyster reefs during the previous year (1999 – 2000) were asked the following question:

> "Would you be willing to pay $X each year in addition to your usual fishing license for the right to fish over clearly marked oyster reefs and maintain the current catch rate per trip? This privilege would be granted only to recreational fisherman who paid the extra fee and the fee would be used to maintain oyster reefs at current conditions."

The randomly assigned dollar value was either $5, $10, $15, $20, or $25. Responses were either ("Yes" = 1) or ("No" = 0). The individual telephone interview respondent's randomly-assigned dollar value, called "Bid Amount", which was included as an independent variable in the willingness to pay estimation model.

Persons with more experience in fishing were hypothesized to hold a higher value for oyster reefs as recreational fishing grounds. Thus anglers with longer experience (measured by the continuous variable "Years Fished") should, according to theory, have a higher willingness to pay.

Table 3-19. Conceptual Model and Parameters

Value of Oysters as Recreational Fishing Grounds = f(Experience, Utilization, Education, and Income)		
Element	**Parameter**	**Predicted Relationship**
Experience	Years Fished	+
Avidity	Days of Saltwater Fishing in Last 12 Months	+
Utilization	Percentage of Angling Time Over Oyster Reefs	+
Income	Ranges (< \$30,000; \$30-\$59,999; \$60-\$74,999; > \$75,000)	+
Education	College Degree or Higher	+
Utilization/Income	Boat Ownership	+

Table 3-20. Empirical Model

Prob (Yes) = F(Bid Amount (-); Reef Rate (+); FFDays12 (+); Years Fished (+); Boat Owner (+); College (+); Inc3060 (+); Inc6075 (+); Incgt75 (+))	
Where:	
Bid Amount	\$5, \$10, \$15, \$20, \$25
Reef Rate	Percentage of Fishing Time Spent over Oyster Reefs
FFDays12	Number of Days Spent Saltwater Fin Fishing in Previous 12 Months
Years Fished	Number of Years of Recreational Fishing
Boat Owner	= 1 if the respondent's household owned a boat; 0 otherwise
College	= 1 if the respondent graduated college; 0 otherwise
Inc3060	= 1 if household income was between \$30,000 - \$59,999; 0 otherwise
Inc6075	= 1 if household income was between \$60,000 - \$74,999; 0 otherwise
Incgt75	= 1 if household income was greater than \$75,000; 0 otherwise

Fishing avidity, the frequency of participation, was also hypothesized to be positively related to willingness to pay. Persons who go fishing more frequently, measured by the continuous variable "FFDays12", the number of days of saltwater fishing in the past 12 months, would be expected to demonstrate a higher willingness to pay. Further, a greater value for oyster reefs would be expected from those who fish over oyster reefs more frequently, measured by "reef rate," the percentage of fishing time over oyster reefs.

Individuals who own boats may also be more avid anglers, as demonstrated by the investment in a marine vessel. Boat owners are also able to gain access to oyster reefs more readily, thus a positive sign was expected for "Boat Owner", a dummy variable for boat ownership.

Persons with more formal education may be more aware of the role of oysters as fish habitat. Therefore, a positive relationship between willingness to pay and "College", a dummy variable for college graduates, was hypothesized.

Angling is a normal good, one for which consumption increases with income. There are four categories of income. Each respondent wais placed in one category, denoted by the appropriate dummy variable. The lowest category (less than $30,000) was treated as the standard and was omitted from the model. A positive sign was expected for each of the income variables.

Finally, a negative relationship was expected between willingness to pay and the bid amount, the randomly selected dollar value on each survey. People faced with a higher "price" are less likely to pay. This negative relationship is indicative of a downward sloping demand curve.

The Theoretical Unit of Value: Welfare Measure

The contingent valuation estimation is based on a question eliciting the willingness to pay to maintain the current quantity and quality of oyster-reef fishing grounds off coastal Louisiana. This distinguishes the nature of the appropriate welfare estimate, a theoretical concept based upon changes in the quantity of the good in question and alternative levels of utility.

Willingness to pay reflects the value of recreational fishing over oyster reefs for an individual with preferences for a bundle of market goods, x, and a non-market recreational fishing good, q, the access to fishing over oyster reefs. These preferences are contained in a utility function

$$U(x, q)$$

which is continuous, non-decreasing, and quasi-concave in x and q. The individual will maximize utility subject to a budget constraint:

max U(x, q) subject to p·x #y

where p is a matrix of prices of market goods x and y represents income. Following the approach used by Mitchell and Carson (1989) and Hanemann (1999), the expenditures function that maximizes this utility problem is

$$e(p, q, U) = Y,$$

where p is a vector of market prices and U is a given level of utility. The variable Y is the minimum level of income required to maintain the level of utility U achieved at price level, p, and quantity, q.

For quantity variations, Mitchell and Carson (1989) claim that WTP can represent a compensating surplus or equivalent surplus when the subsequent quantity q_1 is considered superior to or inferior to the initial quantity q_0. In this survey, the current level of fishing over oyster reefs is assumed to be preferred over the subsequent level of fishing over oyster reefs, which could be reduced (to zero) if the respondent did not pay the fee. Thus, WTP is willingness to pay to avoid a quantity decrease, identified by Mitchell and Carson as an equivalent surplus measure:

$$\begin{aligned} ES &= [e(p_0, q_0, U_1) = Y_0] - [e(p_0, q_1, U_1) = Y_1] \\ &= Y_0 - Y_1. \end{aligned}$$

Equivalent surplus measures the difference in income needed to maintain the level of utility achieved at q_1 when the price level is fixed but the quantity of the non-market good, oyster reef fishing catch, decreases from q_0 to q_1.

The welfare estimate provided by Whitehead and Haab (2001) was also an equivalent surplus welfare measure. Like this study, it estimated the willingness to pay to maintain current fishing access.

The estimate generated by this research is a measure of consumer surplus, the excess of the consumers' total value above current expenditures. Thus, the willingness to pay estimate demonstrates the value of access to oyster reefs as recreational fishing grounds in addition to associated angling expenditures.

Empirical Results

A logit model was run in SAS© with the willingness to pay variable as a function of the others. Results are reported in Table 3-21.

The hypothesized positive relationship was observed for "Reef Rate" at the α = 0.05 significance level. The hypothesized relationship for "Years Fished" is not

Table 3-21. Empirical Results

Parameter	Estimate	Standard Error	X^2	$P > X^2$
Intercept	0.3871	0.4250	0.8296	0.3624
Bid Amount	-0.1315	0.0149	77.4691	< 0.001
Reef Rate	1.2712	0.3171	16.0705	< 0.001
FFDays12	0.00421	0.00246	2.9282	0.0870
Years Fished	-0.00105	0.00614	0.0293	0.8641
Boat Owner	0.1942	0.2355	0.6800	04096
College	0.0857	0.2157	0.1581	0.6909
Inc3060	0.6477	0.3090	4.3948	0.0360
Inc6075	0.9139	0.3371	7.3509	0.0067
Incgt75	0.5133	0.3795	1.8296	0.1762
Likelihood Ratio	117.4665	**$P > X^2$**	< 0.001	N = 554
Percentage Concordant = 75.6		**Percentage Discordant =** 24.2		

significant at the $\alpha = 0.05$ significance level significant (although it is significant at the $\alpha = 0.10$ significance level). This suggests that willingness to pay to maintain access to oyster reefs increases with the rate of use of the resource in question but not with the tenure of anglers' experience with angling in general.

The expected positive relationship for "Boat Owner" was not observed. The wide spread occurrence of boat ownership among reef users (77.52% of whom owned a boat or shared a household with somebody who did) may have masked the importance of boat ownership as an explanatory factor in fishery valuation. McConnell and Strand (1994) found that boat value was an influential factor in an individual's willingness to pay for angling opportunities. This information, however, was not included in this data set.

The variable "College" was not significantly related to willingness to pay. Thus the hypothesis that the value of oyster reefs as fishing grounds is positively related to education is not supported. The possible correlation between this variable and income suggests that this finding should be viewed with some caution.

The relationship for income is complex. The relationship between willingness to pay and income for the range from $30,000 to $59,999 and the range from $60,000 to $74,999 is positive at the α = 0.05 level. The relationship for the highest income range, greater than $75,000, is not significant. This suggests a quadratic relationship between income and the value of oyster reefs as recreational fishing grounds. Participation and value may perhaps increase with income but taper off or even decline at higher levels where alternative forms of recreation may be available and affordable. Alternatively, correlation between education (i.e., college) and higher income may "mask" the significance of higher income levels on the demand for oyster reefs for recreational fishing opportunities.

The expected negative relationship between willingness to pay and "Bid Amount," the randomly-assigned survey dollar amount, is significant at the α = 0.05 level. A downward-sloping demand curve is thus evident. Integrating under the demand curve over the dollar values, holding all other variables at their mean values, generates an estimated willingness to pay of $13.21[2] in addition to existing license fees.

Estimating the Total Value of Louisiana's Oyster Reefs as Recreational Fishing Grounds

To obtain an estimate of aggregate value from an estimate of average willingness to pay, one must start with the population and participation rate, following McConnell and Strand (1994):

[2] This willingness to pay estimate is slightly less than the annual resident saltwater license fee [$15.00], the sum of the fees for the required resident basic fishing license [$9.50] and saltwater fishing license [$5.50].

Total Willingness to Pay =

(Population)x(Participation Rate)x(Representative Angler's Willingness to Pay).

The participation rate may be gleaned from the telephone survey, a sampling of anglers, but not the intercept survey, a sampling of angling days. The sampling method employed in the execution of the telephone survey, however, may introduce a potential source of bias. To assure an adequate sample of reef users for the willingness to pay estimation, the telephone survey intentionally over-sampled Louisiana resident anglers who had fished over an oyster reef on the day they were intercepted for the M.R.F.S. Survey. While only 23.3 percent of all Louisiana resident anglers had fished over an oyster reef on the day of intercept, 27.8 percent of the anglers contacted by the telephone survey had fished over an oyster reef on the day that they were intercepted for the M.R.F.S. Survey. To avoid bias, this research excludes the 211 telephone survey participants who fished over an oyster reef on the day of intercept and who were targeted in disproportionate numbers in the telephone survey process. Of the remaining 548 telephone respondents, 345 (62.96 percent) fished over an oyster reef at least once during the year. This may be treated as the percentage of resident saltwater anglers who use oyster reefs.

According to the U.S. Fish and Wildlife Service, there were 386,000 resident saltwater anglers in 2001. Of these, it is assumed that 62.96 percent, or 243,026, use oyster reefs at some point during the year. Multiplying this number by the average willingness to pay ($13.21) produces an aggregate annual willingness to pay estimate of $3,210,368.

This estimate relies upon a resident saltwater angler population estimate that has been questioned by critics of the U.S. Fish and Wildlife Service's Survey of Hunting, Fishing, and Wildlife-Related Activities. It may be more reliable to depend upon a more observable measure of participation, i.e., the number of saltwater fishing licenses.[3] In fiscal year 2000-01, which corresponds to the survey administration period, the Louisiana Department of Wildlife and Fisheries issued 316,000 resident saltwater recreational fishing licenses. Assuming that 62.96 percent of these anglers fished over oyster reefs, the estimated number of oyster reef anglers is 198,954 and the estimated annual aggregate willingness to pay is $2,628,182.

A third estimation employing this approach utilizes the estimate by the National Marines Fisheries Service of 653,483 Louisiana resident marine anglers in 2001. Based on this estimate, the estimated number of anglers who fish over oyster reefs would be 411,433, and the aggregated annual willingness to pay would equal $5,435,029. This estimate is twice that derived from the U.S. Fish and Wildlife Service Survey because it is based on the N.M.F.S. angler population estimate. In a desire to avoid anything other than a conservative estimate of user value, this figure, though reported here, is discounted.

Aggregating Mean Willingness to Pay, Days of Saltwater Fishing

The utilization rate of oyster reefs estimated above (62.96 percent) is derived from a telephone survey of M.R.F.S. Survey intercepted anglers, a population of anglers who may not be representative of Louisiana resident saltwater anglers as a whole. The anglers intercepted in the M.R.F.S. Survey have reported a larger number of saltwater fishing days than is reported for Louisiana anglers in other studies (U.S. Fish and

[3] This number may be an under-estimate as it does not account for the number of anglers without licenses.

Wildlife Service, 1998; Felder and Leahy, 1998). The sample may possess an avidity bias, a disproportionate inclusion of anglers who fish at a rate above the statewide average. This may be an unavoidable result of the M.R.F.S. Survey sampling procedure. Anglers who fish more frequently over a larger number of fishing days are more likely to be included in the M.R.F.S. Survey.

The M.R.F.S. Survey is more a sample of saltwater fishing days than a sample of saltwater anglers. From the percentage of Louisiana resident M.R.F.S. Survey respondents who fished over an oyster reef on the day of intercept, it is surmised that 23.3 percent of all resident saltwater angler days are spent in part over oyster reefs.

The U.S. Fish and Wildlife Service, in a telephone sample of the Louisiana population, estimated the number of saltwater angling days fished by Louisiana residents. In 2001, this figure was estimated to be 4,113,000 angling days. Multiplying this by 23.3 percent yields an estimate of 958,329 resident angling days spent at least in part over oyster reefs.

To estimate the number of oyster reef anglers, one needs an estimate of the number of days over oyster reefs per angler. This should be substituted into the following equation:

$$\frac{\text{Total Number of Days over Oyster Reefs}}{\text{(Number Days over Oyster Reefs/Reef Angler)}} = \text{Number Reef Anglers}$$

Aside from the data derived from the survey described in this report, there are no estimates for the number of days spent by the typical angler over oyster reefs. The results from the survey are likely to suffer from some upward bias based on sample avidity, resulting in an over-estimate of oyster reef days per reef angler that appears in the denominator of the above equation. Thus, there is likely to be some downward bias in the estimation of the number of oyster reef anglers. In the user sample, the average number of days spent fishing over an oyster reef per oyster reef angler was 11.65. Plugging this into the estimation equation produces:

$$\frac{\text{958,329 Days Over Oyster Reefs}}{\text{(11.65 Days over Oyster Reefs/Oyster Reef Angler)}} = \text{82,260 oyster reef anglers}$$

Multiplying this estimate for the population of oyster reef anglers by the average willingness to pay yields an aggregate willingness to pay of $1,086,655.

The National Marine Fisheries Service's statistics regarding the frequency of angling activities are difficult to apply. These data list the number of trips in the state but do not provide the total number of days. These figures do not fit into this method for calculating the number of oyster reef anglers.

Table 3-22 presents the range of estimates for Louisiana resident saltwater anglers' willingness to pay to maintain access to oyster reefs as recreational fishing grounds. These values estimate consumer surplus, the value above current expenditures for saltwater angling.

Comparison to Other Studies of Gulf of Mexico Fishing Values

Estimates of the value of non-market resources are highly particular. Comparisons across different non-market valuation studies of recreational fishing are difficult to make. Quantity and quality variables vary across geographical areas. Areas closer to highly populated areas or located in frequently visited tourist areas may likely generate a different set of values than more isolated areas. Areas with many substitute recreational opportunities will also be valued differently than areas with few such alternatives. Format

Table 3-22. Total Willingness to Pay Estimates
Based on Angler Population Estimates

	Source		
	Resident Saltwater Recreational License*	**National Survey of Fishing, Hunting, and Wildlife-Associated Recreation****	**Marine Recreational Fishing Statistics Survey*****
Angler Population	316,000	386,000	653,843
Oyster Reef Anglers	198,954	243,026	411,433
Total W.T.P.	$2,628,182	$3,210,368	$5,435,029

Based on the Estimated Number of Recreational Angling Days

	National Survey of Fishing, Hunting, and Wildlife-Associated Recreation**
Residents' Recreational Fishing Days	4,113,000
Estimated Days over Oyster Reefs	958,329
Oyster Reef Angler Estimates	82,260
Total W.T.P.	$1,086,655

* Source: Louisiana Dept. Wildlife and Fisheries
** Source: U.S. Fish and Wildlife Service
*** Source: National Marine Fisheries Service

differences may affect valuation estimates: variations in valuation technique (e.g., contingent valuation versus random utility model), valuation format (willingness to pay versus willingness to accept compensation), technique (open-ended format versus dichotomous choice), unit of change (an increase or increase versus decrease), and differences in payment vehicle (licenses versus voluntary payments). All of these things will contribute to variations in the estimated value of a recreational angling resource (Freeman, 1993).

Milon and Thunberg (1994) estimated the value of an extra fish, ranging from $0.03 to $1.94, depending on species. McConnell and Strand (1994) estimated the value of a one-half fish increase in expected catch in several states along the Atlantic coast. Values ranged from $0.12 to $17.46, depending on the category of fish. Whitehead and Haab (2001), in a variation on the value of a change in catch rate, provided an estimate of the value of avoiding a reduction in bag limits for a variety of species. Parson and

Hauber (1998) estimate the loss associated with a decrease in catch rate associated with water quality degradation. These studies examining the value of a change in fishery productivity provide no easily interpreted comparison with the present project.

A number of studies estimate the annual value of fishing access, the same entity valued in this research. The value of annual access to a red drum fishery in Florida varied from $61.58 to $90.73, estimated from a willingness to pay for continued access (Haab, Whitehead , and McConnell, 2001). The value of access to saltwater angling in Florida was $585, according to a willingness to sell study (McConnell and Strand, 1994). In a variety of studies cited in Freeman (1993), annual access to a multi-species fishery ranged from $2.29 for one reef in Florida to $4,141 for an area of Texas.

The mean value of annual access to oyster reefs in Louisiana is roughly equal to the mean value of per trip access in a random utility model. Haab, Whitehead and McConnell (2001) estimated the value of a trip in Louisiana ($11.68) and the Gulf of Mexico as a whole ($82.22).

The average willingness to pay for access to Louisiana oyster reefs is low compared to some other studies. This may be a result of the relatively broad area included in the valuation study. Higher values tend to be associated with selected or specific sites for which fewer comparable substitutes exist. For oyster reefs along the entire coast of Louisiana, there are numerous substitute angling opportunities, likely suppressing the value of oyster reefs as recreational fishing areas.

Chapter 3-6. Summary and Conclusion

Louisiana's oyster reefs are clearly an important part of the state's recreational fishery. Nearly 23 percent of all recreational fishing days in Louisiana (approximately 1,060,771 days) are spent, in part, over oyster reefs, according to the National Marine Fisheries Service's Marine Recreational Fishing Statistical Survey. The actual rate of utilization may exceed this estimate if a substantial number of anglers fish over oyster reefs but are unaware of it.

The average Louisiana resident oyster reef anglers are experienced, with 27 years of fishing experience, and active, with 30.9 saltwater fishing days in the year prior to the survey. Approximately 35 percent of the average oyster reef angler's total saltwater fishing time is spent over oyster reefs.

The average oyster reef angler is relatively well-educated (with a higher level of formal educational attainment than the average Louisiana resident). Perhaps coincidentally, oyster reef anglers also claim relatively high income. While half of the state's population had a household income above $30,466 (the state median), nearly 90 percent of the oyster reef anglers claimed a household income in excess of $30,000. Boat ownership, another factor that may be related to income, is high among oyster reef anglers. Over three-quarters of all oyster reef anglers lived in a household in which somebody owned a boat.

Oyster reef anglers seemed purposeful in their decision to fish over oyster reefs. They are less likely than other anglers to fish without a specific target fish species. Among those who did identify a specific target species, over 95 percent pursued spotted seatrout and red drum.

Many oyster reef anglers appear aware of the reefs' biological productivity. The portion of oyster reef anglers selecting reefs for the quantity of available fish is roughly equal to the portion of anglers selecting them for the variety of fish available.

Many of these factors (income, education, boat ownership, experience, avidity, and rate of reef utilization) were considered in the calculation of willingness to pay to maintain Louisiana's oyster reefs among the state's resident oyster reef anglers. The average value of access to oyster reefs for a Louisiana oyster reef angler was $13.21. Willingness to pay was positively and significantly related to avidity and reef utilization. Across an intermediate range of income ($30,000 to $75,000), willingness to pay increased and then declined among respondents with a household income above $75,000.

The aggregate value of access to oyster reefs as recreational fishing grounds ranged between $1.1 million and $5.4 million with a median value of $2.9 million, depending upon the method used to estimate the total population of oyster reef anglers. The value of oyster reefs as recreational fishing grounds represents their value above recreational angling expenditures.

This research supports claims that Louisiana's oyster reefs possess a value above that of commercial oyster harvests. The state's oyster reefs are used on over one million angling days by hundreds of thousands of active and experienced anglers. Further, there is little evidence that this recreational fishing activities interferes substantially with the primary purpose of the reefs, the production of oysters for commercial harvests and processing. The use and value of oyster reefs as recreational fishing grounds may thus be used in the consideration of oyster reef maintenance and enhancement programs.

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Section 4.
Performance Assessment Of Three Different Cultch Materials for Oyster Seed Production at The Half-Moon Island Plant Site

Prepared for the:

LOUISIANA DEPARTMENT OF WILDLIFE & FISHERIES

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PREFACE

This project was contracted by the Louisiana Department of Wildlife and Fisheries under contract number **CFMS#564461**. The project was part of a Louisiana Department of Wildlife and Fisheries's three-year project entitled, "**Louisiana's Oyster Shell Recovery Pilot Project**." The Department's project was funded by the National Marine Fisheries Service under **NOAA Grant No. NA96FK0188**.

Introduction

In September 2000, the Louisiana Department of Wildlife and Fisheries (LDWF), under contract number CFMS#564461, contracted with Cirino Consulting Services (CCS) to direct and coordinate the Fall (October 2000) oyster-cultch planting activity at the recently selected Half-Moon Island Plant Site and to direct and coordinate a performance assessment of three (3) different cultch materials at that site. The identification and selection of the Half-Moon Island site as an area for oyster-cultch planting and performance assessment of different oyster-cultch materials was part of a project performed by CCS under a separate LDWF contract (contract number CFMS#550089). A project report for those activities entitled "Investigation and Identification of Selected Areas in Lake Borgne, Louisiana, Suitable for Oyster Cultch Planting" was submitted to the LDWF in May 2000.

These projects were part of a LDWF's three-year project entitled, "Louisiana's Oyster Shell Recovery Pilot Project." The purpose of the LDWF's three-year project is to investigate the feasibility and utility of recycled, processed oyster shells as cultch material for oyster-reef restoration. The objective of the LDWF's project is to develop and implement methods to restore and enhance suitable shellfish (oyster) habitats on Louisiana's public seed grounds that were lost or damaged as a result of Hurricane Andrew (August 1992) by developing a framework for recycling oyster shells for use in oyster-reef restoration and by comparing alternative cultch materials for restoring oyster reefs. Funding for all of these projects was provided by National Marine Fisheries Service (NMFS) Grant No. NA96FK0188.

The scope of services specified in CCS's September 2000 contract (CFMS#564461) were as follows:

1. Design, direct, and coordinate an oyster cultch planting and sampling methodology to assess the performance of various cultch materials for successful oyster recruitment and subsequent market production.

2. Coordinate and direct the scheduled Fall (October 2000) oyster-cultch planting activities.

3. Identify, locate, and mark oyster-cultch planting area(s).

4. Photo-document and verify oyster-cultch planting activities.

5. Record GPS coordinates for planted area(s).

6. Prepare a report on oyster-cultch planting activities.

7. Direct and coordinate cultch performance assessment sampling and data analyses.

8. Prepare a report on the performance of the various cultch materials.

A report of the Fall (October 2000) oyster-cultch planting activities, entitled, "Preliminary Summary Report of the Fall (October 2000) Shell-Planting Activities at the Half-Moon Island Plant Site" was prepared and submitted to LDWF by CCS in November 2000. That report addressed Items 1 through 6 of the scope of services. This report addresses Items 7 and 8 of the scope of services and completes the terms of contract number CFMS#564461.

Materials and Methods

Cultch Materials and Assessment Design

The LDWF selected the three (3) different cultch materials for the performance assessment study. The three materials selected were: (1) Crushed Concrete #57, (2) Crushed Limestone #57, and (3) Crushed Oyster Shells. The LDWF contracted with Pontchartrain

Materials Corporation (PMC) of New Orleans, Louisiana, for supply and delivery of the cultch materials. The crushed concrete and limestone were material products normally handled by PMC. The oyster shells were purchased by PMC from Louisiana oyster processors and hauled to PMC where they were crushed to approximate the size of the #57 concrete and limestone. The LDWF selected this cultch size because it had been successfully used before and for its propensity to produce single oysters. Production of single oysters is desired by oyster harvesters, because the labor associated with "culling" (breaking apart a cluster of oysters) is reduced.

The size specifications for #57 crushed concrete and limestone are based on the percent of the material that will pass through certain-sized gradation sieves. According to PMC officials, size #57 specifications are: 100% passage through a 1.5-inch sieve (average 100%); 95 to 100% passage through a 1.0-inch sieve (average 95%); 25 to 60% passage through a 0.5-inch sieve (average 28%); 0 to 10% passage through a #4 sieve (average 8%); and 0 to 5% passage through a #8 sieve (average 3%). Approximately 200 cubic yards of each cultch type were provided for the performance assessment study.

An unplanted area at the southwest corner of the Half-Moon Island Plant Site was selected for the cultch-performance study (See Figures 4-1 & 4-2). Based on the small amount of material per cultch type available for the assessment study (200 cubic yards each), CCS chose to limit the number of cultch test-plots to three plots each per cultch type (3 test-plots per cultch type x 3 cultch types = 9 test-plots). An alternating configuration of three (3) test-plots closely spaced in a row, with one (1) test-plot of each cultch type in the row, was selected to eliminate or minimize the effect of spatial

Figure 4.1 General Study Area Map

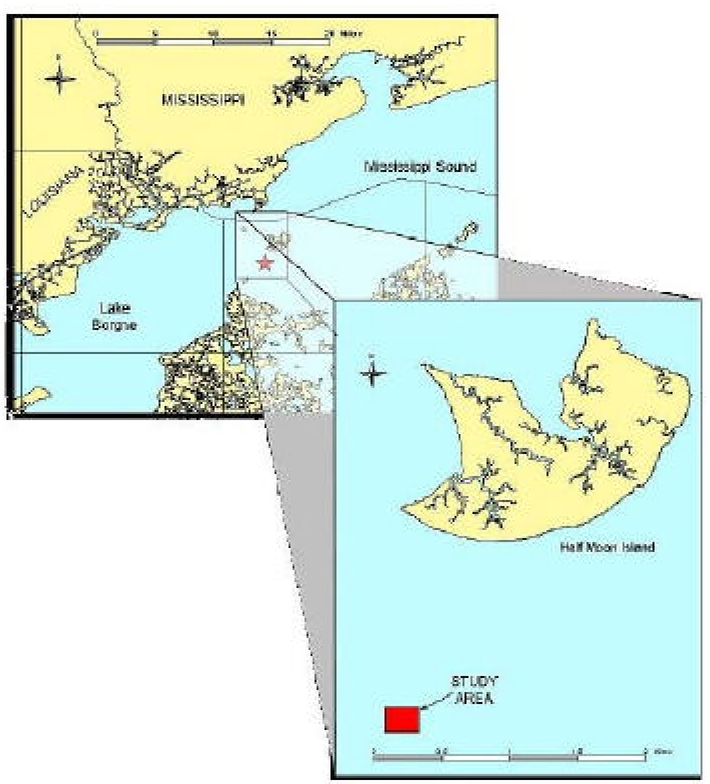
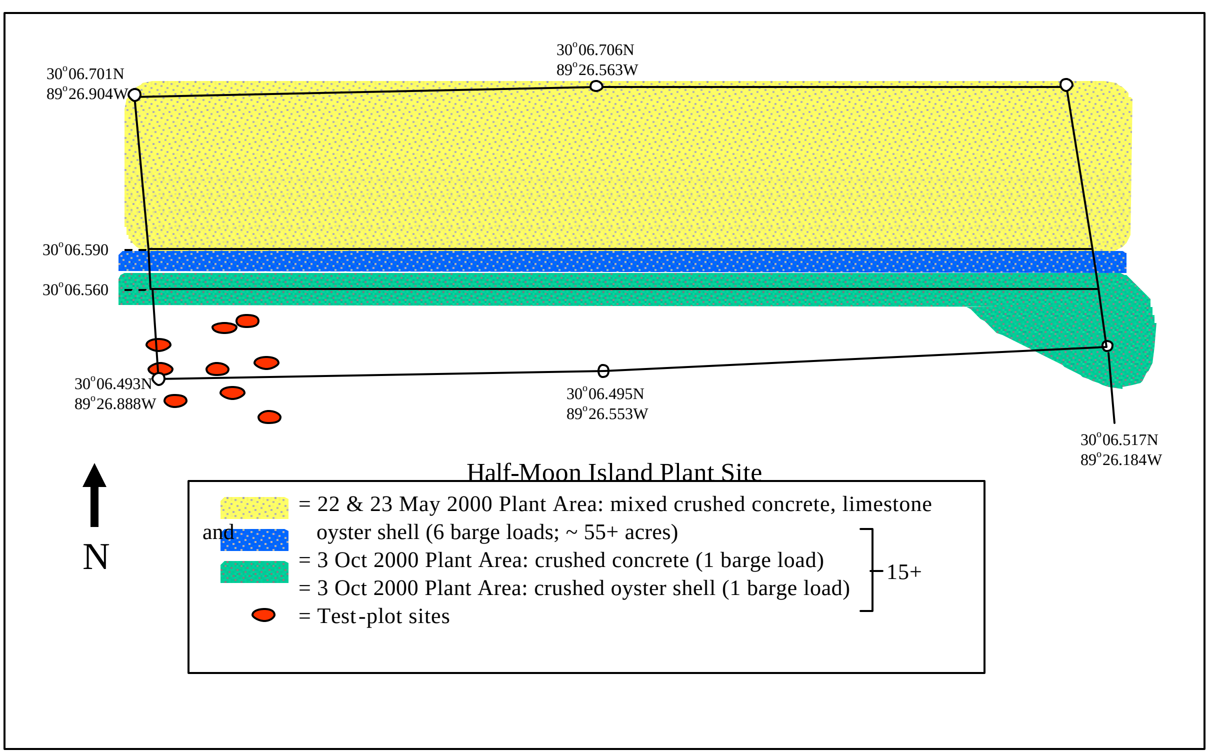
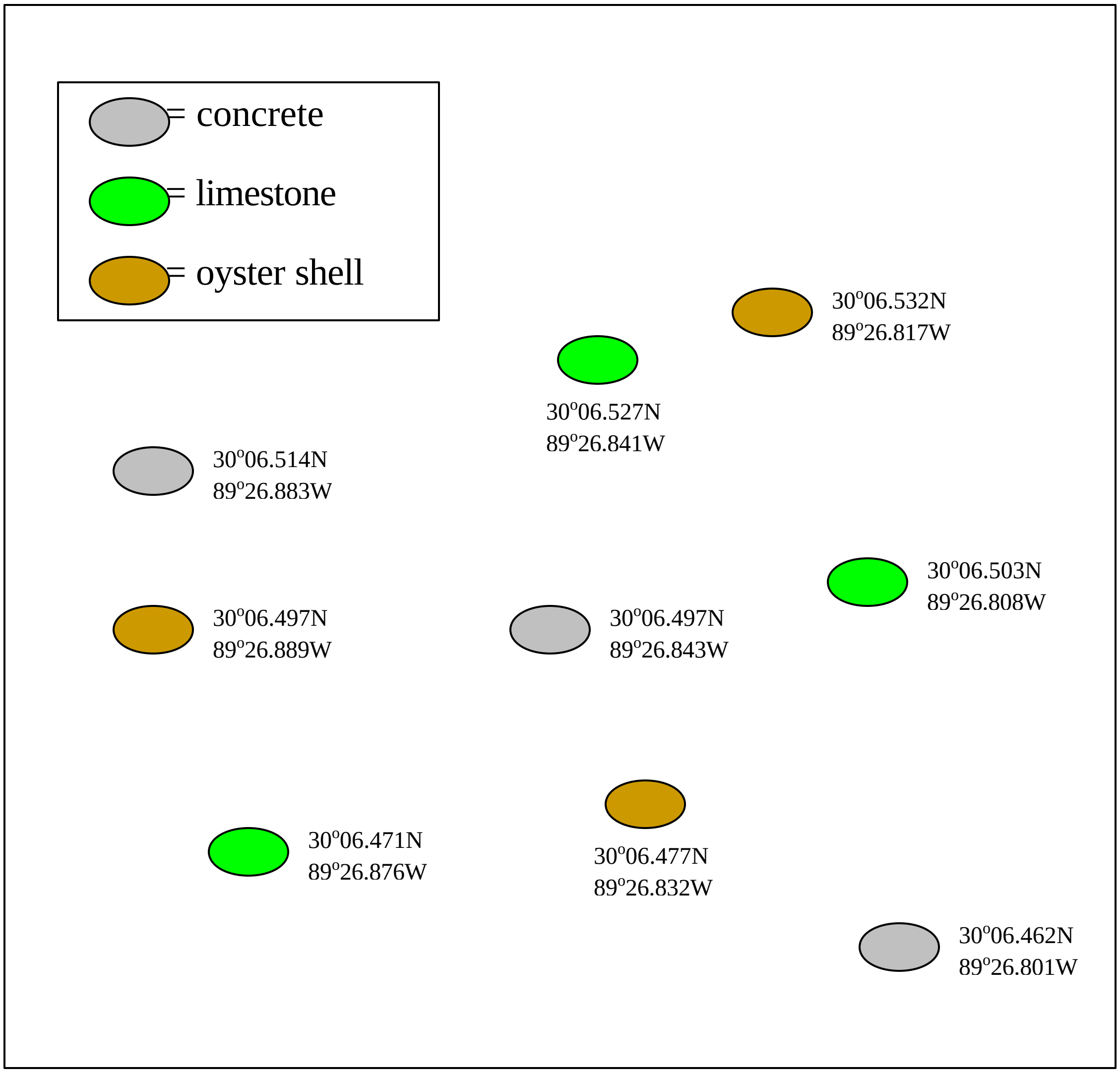


Figure 2. Map of Half Moon Island Plant Site
(Cultch coverage was not complete throughout plant areas)



distribution on cultch-type performance. This pattern also allowed for each of the cultch types to be located fairly evenly with respect to row orientation (i.e., north, middle, or south rows, and east, middle, or west rows) using the fewest number of sites in consideration of the small volume of cultch material available (Figure 4-3).

Figure 4-3. Map of Test Plots



Performance assessment was based on the numbers of live oysters per test plot and their mean size in millimeters for each of the cultch types. A period of between 6 to 9 months was selected between cultch planting and performance sampling to allow sufficient time for oysters to set on the cultch and grow to seed size of 1 to 3 inches (25 to 76 millimeters). Generally, it requires 18 months for oysters to reach a size of 3 inches; however, the 6-to-9-month period was deemed sufficient for most of the setting oysters to reach seed size.

The numbers of live oysters per test plot and their mean size in millimeters (25.4 mm = 1 inch) was determined by using a SCUBA diver to collect three (3), 0.33-meter-square quadrate samples from each of the nine (9) separate test-plots. This design provided data from nine (9) individual samples per cultch type on the numbers of live oysters and their mean sizes and for statistical analyses of those data (3 quadrate samples per test-plot x 3 test-plots per cultch type = 9 quadrate samples per cultch type). Live oysters from the 0.33-meter-square quadrate samples were identified and measured in the laboratory. The number of live oysters and the corresponding mean size were calculated for each quadrate sample. These measurements were statistically analyzed for significant differences among cultch types and test-plot locations.

Site Selection and Test-Plot Planting

An area at the southwest corner of the Half-Moon Island Plant Site was selected for the test-plot plantings because it was within the shell plant site and was farthest away from the previous cultch planting of May 2000 and the scheduled October 2000 cultch planting (See Figure 4-2). On 2 October 2000, John Cirino of CCS conducted a cursory "poling" survey of the selected area with a cane pole to check for an appropriate bottom firmness that would support the cultch plantings. Mark Lawson of the LDWF's Slidell office assisted with the poling survey and operated the LDWF's 25-foot, Boston Whaler vessel from which the survey was conducted. Cane poles flagged with one (1) of three (3) different colors corresponding to the different cultch types were used to mark nine (9) potential test-plot sites (Yellow for Concrete, Green for Limestone, & Pink for Oyster Shells). The latitude and longitude coordinates for the nine (9) cane poles were recorded with a SI-TEX, model HG-7, hand-held, global positioning system (GPS) receiver that was differentially corrected with a SI-TEX, model SBR-91, differential global positioning system (DGPS) beacon receiver.

On 3 October 2000, cultch materials and planting equipment were transported to the site by PMC with tugs and barges from their New Orleans, Louisiana, facility. The cultch materials were loaded and transported on a separate barge in three (3) separate piles of approximately 200 cubic yards each. Cultch materials were planted by a barge-mounted crane using a 4.5-cubic-yard clam bucket (see Appendix C). The cultch barge was tied along side of the crane barge for planting operations and the crane barge was equipped with spuds to anchor it in position for cultch planting. This barge flotilla was maneuvered by a tug into position at each of the nine (9) marked, test-plot sites under the direction of John Cirino of CCS.

With the flotilla spudded in position, the cultch material was planted around the cane pole marker using a swinging-dump action that broadcasted the cultch material back and forth and around the central point marked by the cane pole (see Appendix C). As the material was planted at each site, John Cirino of CCS checked the coverage and thickness of the planted material with a cane pole at frequent intervals between successive buckets to determine and direct a satisfactory planting density and area coverage. The planting objective was to produce an area with a "crown" of cultch material around the cane pole marker at each test-plot site that was above the surrounding bottom level and that could be readily located again using a cane pole and the recorded GPS coordinates.

Upon completion of the test-plot plantings, a 20-foot section of 2-inch-diameter PVC pipe was used to mark the crown area of each test-plot site. The GPS coordinates of these PVC markers were recorded with the LDWF's Furuno Navigator GPS without differential correction. Direction of the test-plot plantings, marking of the test-plot sites with the PVC pipes, and recording of the GPS coordinates were done by John Cirino (CCS) aboard the LDWF's 25-foot Boston Whaler vessel with the assistance of Mark Lawson (LDWF).

Test-Plot Sampling

Following the elapsed time period allowed (6 to 9 months) for oyster setting and growth, the crown area of each test-plot site was relocated using the PVC marker or by poling with a cane pole around the recorded GPS coordinates for the site and marking the crown area with a flagged, cane pole. Flagging was color coded to correspond to each of the different cultch types as described above under Site Selection & Test-Plot Planting. Once the site was marked, the LDWF vessel was anchored with a stern quarter adjacent to the cane pole marker (see Appendix C).

When the vessel was properly positioned, a 30-pound, concrete, diver-descent weight with an attached 0.5-inch-diameter, nylon line was dropped overboard along side of the cane pole marker. The 0.33-meter-square quadrate frame was attached to the descent weight with a short piece (approximately 3 feet) of 0.125-inch-diameter, nylon line. The descent weight and line were used to guide the diver's descent and ascent to and from the marked, crown area. The descent weight also assisted the diver with maintaining position on the bottom while collecting quadrate samples during swift tidal currents. An appropriate length of the descent line for the water's depth and swinging of the vessel due to wind, current, and sea state was deployed such that the vessel's movement would not drag the descent weight off the marked, crown area. The upper portion of the descent line was cleated to the LDWF vessel and a large float (plastic boat fender) was attached to the tag end of the descent line. In case the line needed to be released from the vessel to keep from pulling the weight and/or diver offsite, the large float served to mark the descent line and to assist the diver at the surface.

The SCUBA diver descended along the descent line to the descent weight and attached quadrate frame. The diver carried a 5-gallon, perforated, aluminum basket (the type of basket typically used as an insert in a larger pot for boiling seafood) for collection of the cultch material within the quadrate frame. The basket was tethered to the vessel with a 0.25-inch-diameter, nylon line in the same manner as the descent line, except that a smaller bullet float (the type occasionally used for marking crab traps) was used for marking purposes. Personnel aboard the vessel retrieved the collected, cultch sample with the basket line.

When on the bottom at the quadrate frame, the diver checked to ensure that the frame was still within the crown area. If underwater visibility permitted, this was done by sight; however, if visibility was not suitable, this task was done by feeling the bottom area. Once the diver confirmed that the frame was within the crown area, the basket was placed beside the frame and the diver collected the cultch material within the frame by hand and placed it in the basket. The diver removed all of the cultch material within the frame down to the level at which the cultch was no longer available for oyster attachment (usually between 3 to 6 inches). With suitable underwater visibility, the diver was able to visually identify this level as the point at which none of the cultch within the frame was covered with oysters or other attaching (or fouling) organisms such as algae, barnacles, bryzoans, mussels, et cetera. If visibility was not suitable, the diver achieved this level by removing all of the cultch material until he could feel that the remaining cultch was buried by cultch and/or sediment. When collection was completed, the diver would surface along either the descent or basket line and personnel in the vessel would retrieve the basket with the collected sample.

The retrieved sample was rinsed in the basket by jigging it overboard at the water's surface, and the basket was then emptied into a large, plastic sorting tray (see Appendix C). The empty basket was returned to the diver and the diver descended along the descent line to the descent weight and attached quadrate frame. The diver would move the descent weight and frame a short distance away (approximately 3 to 5 feet) from the previous sample area, but remaining within the crown area, and randomly toss the frame away from the weight and allow it to settle on the bottom. Once the diver confirmed that the frame was within the crown area, the sampling process was repeated until three (3), 0.33-meter-square samples were collected at each test-plot site.

The retrieved sample was sorted and all live oysters and cultch pieces with evidence of attached (or fouling) organisms were placed in either 1- or 2-gallon, plastic Zip-loc Brand bags, or placed loose in the bottom of a labeled and lidded, 3-gallon, plastic bucket, depending on the size of the sample retained. In some instances, the entire sample was retained due to time consideration and sample composition. All bagged samples were placed in labeled and lidded, 3-gallon, plastic buckets. A 3- by 5-inch index card identifying the sample was placed in the bag or bucket with each sample. Collected samples were returned to CCS facilities and held in a refrigerated cooler until processed.

Sample information was recorded on a station data form and included sample identification, sample date, sample time, bagged or loose sample, bucket number, water depth, bottom water salinity, bottom water temperature, and sample remarks. Bottom water samples were collected with a 750-ml, LaMotte water-sampler. Bottom water salinities were determined with an AO Goldberg refractometer to the nearest part per thousand and bottom water temperatures were determined with an Enviro-Safe armored thermometer with a citrus-based green liquid to the nearest half-degree Celsius. Water depths at each site were determined with a cane pole marked at 1-foot intervals, but were not corrected for tidal influence. Information on field activities and conditions were recorded on a general field data form and included such information as personnel, equipment, nature and times of activity, sea state, and weather conditions.

Data and Statistical Analyses

Cultch samples were examined in the laboratory in a lighted field and with the aid of magnifying lenses. Live oysters were measured to the nearest millimeter (1 inch = 25.4 mm) with a stainless steel Vernier caliper and recorded on a data form. Old and fresh dead, oyster boxes and valves were also measured and recorded. The numbers of live oysters on a cultch piece were identified by grouping the recorded measurements together. General remarks on the abundance and size of fouling organisms such as barnacles, bryzoans, and mussels associated with the sample were made, along with any other notable or descriptive sample remarks.

The live oysters measured were tallied in 3-mm size groups to determine the mean size and total number of live oysters for each sample. These data were analyzed to detect differences in the abundance of oysters or the mean sizes of oysters between the different cultch types planted. Additionally, these data were analyzed to determine if differences existed within a cultch type because of spatial distribution of the test-plot sites.

The Kruskal-Wallis test was used to compare abundance and mean size data among cultch types. This test utilizes ranked data to determine statistical differences in a data set and may be used when test assumptions for parametric analyses, such as a One-Way Analysis of Variance (ANOVA), are not met. Comparisons were considered to be statistically significant at the $p < 0.05$ level. If a significant difference was detected with the Kruskal-Wallis test, pair-wise comparisons of the data were made between individual cultch types with the Mann-Whitney U-test.

Results and Discussion

Cultch Materials and Assessment Design

The cost and availability of a cultch material is a viable factor in assessing its use; however, an economic analyses was not part of this study. A separate part of the LDWF's three-year project was scheduled to conduct an economic assessment of cultch materials for oyster-reef restoration. Costs of the cultch materials used in this study were not known and were not included in the performance analyses herein; however, some general information on costs and availability of the cultch materials used herein was obtained from PMC is provided for perspective.

According to PMC officials, crushed concrete #57 and crushed limestone #57 are readily available materials, though large volumes (greater than 2,000 cubic yards) of crushed concrete may require additional time to obtain because it comes from recycling old concrete. Recycling sources normally come from the demolition of old or dilapidated concrete structures and while the volume available from a single source may be significant, transportation and processing logistics may vary greatly and increase costs. Oyster shells pose a bigger problem because large volumes from a single source or general location are not readily available. Sources of oyster shells are scattered among the many oyster processors both in and out of Louisiana and transportation logistics are considerable. Crushed limestone is more readily available in larger quantities because it is mined and manufactured by an established industry; however, shipping costs (from Kentucky or Mexico) also increases its costs.

Costs for crushed concrete #57 and crushed limestone #57 on the yard at PMC facilities in New Orleans, Louisiana, were currently \$12.50 and \$16.50 per cubic yard, respectively. Crushed oyster shells were not currently available from PMC because all of its stockpiled oyster shells were committed to an upcoming oyster-reef planting effort in Mississippi. Transportation costs vary based on volume ordered and delivery destination. Based on the factors noted above, the purpose and objective of the LDWF's three-year project was well warranted.

The 200-cubic-yard volumes of each of the cultch materials used in this study were delivered as part of a larger LDWF cultch-planting effort that was originally conducted in May 2000 at the Half-Moon Island Plant Site. Completion of that planting effort was delayed until October 2000 because of difficulty in obtaining the desired volume of oyster shells. According to PMC and LDWF officials, greater than 40%, by volume, was lost when the oyster shells were crushed. Considering the volume that was lost when the shells were crushed, and that the crushed oyster shells exhibited the poorest performance in terms of the numbers of live oysters caught, oyster shells were not a good cultch material for oyster seed production when crushed to approximate size #57 concrete and limestone.

The performance assessment design proved satisfactory. The alternating configuration of three (3) test-plots closely spaced in a row, with one (1) test-plot of each material type in the row, eliminated the effect of spatial distribution on cultch-type performance. This configuration and the number of test-plots selected (9) also proved successfully for constructing the test-plots with the objective crown areas in lieu of the small amount of cultch material available for test-plot construction. In the 6 to 9 months between cultch planting and performance sampling, the oysters that set on the cultch had grown to seed size as desired; however, mean sizes were smaller than expected.

Differences in the performance of the cultch materials tested were detected and statistically verified using the numbers of live oysters per test plot and their mean size in millimeters for each of the cultch types. While the relatively low number of samples collected (3 quadrates at each site) prevented the use of a parametric analysis of the data such as an One-Way Analysis of Variance (ANOVA), the data did enable the use of the Kruskal-Wallis test which is the non-parametric equivalent of an ANOVA. The collection of additional samples to facilitate utilizing parametric analyses would have increased the cost of the project above the desired budget limit and, based on the definitive results obtained, was not necessary.

Site Selection and Test-Plot Planting

On 3 October 2000, the nine (9) test-plot sites were successfully planted with the respective cultch types as described in the corresponding section above under Materials & Methods. All nine (9) of the cane pole markers set the day before were present upon arrival at the site. PMC delivered and planted approximately 197 cubic yards of #57 crushed concrete and 208 cubic yards of #57 crushed limestone. The exact volume of the crushed oyster shells delivered and planted was not known because, contractually, it was determined prior to crushing. The volumes of all three (3) cultch piles on the cultch barge appeared equal and all three (3) of the test-plots of crushed oyster shells were successfully planted with the volume delivered.

Based on the approximate volume of 200 cubic yards of each cultch material type, the 4.5-cubic-yard clam bucket for planting, and the design to plant three (3) sites per cultch type, approximately 66.6 cubic yards (or 14.8 full buckets) of each cultch material were available for each site. Therefore, planting coverage and thickness were closely monitored at each site as described in the Materials & Methods section above. Using the methods described therein, the objective of establishing a crown area was successfully accomplished at all nine (9) sites.
The numbers of buckets planted at each site were as follows: Northwest Concrete - 13, Middle Concrete - 12, Southeast Concrete - 14, North Middle Limestone - 14, East Middle Limestone - 12, Southwest Limestone - 16, Northeast Shell - 12, West Middle Shell - 11, and South Middle Shell - 15.

The swinging-dump action of the crane and clam bucket distributed cultch materials around the cane pole marker within an area with a radius of approximately fifty (50) feet. Near the perimeter of the planted area, the layer of cultch material was thin (less than 1-inch thick) and, in some spots, slightly buried. Moving towards the area's center, the thickness of the cultch material gradually increased and a definitive crown area with a radius of approximately twenty-five (25) feet was detectable around each cane pole marker.

These crown areas were easy to locate by poling the bottom with a cane pole in the vicinity of the recorded GPS coordinates for a test-plot site. By moving back and forth around the coordinates' location, the cultch material could be detected and its thickness felt with the cane pole. By feeling the thickness of the cultch material layer and moving towards increased thickness, the crown area could be located. As one moved from the perimeter towards the central crown area, the thickness of the cultch material would gradually increase, along with its resistance to insertion of the cane pole through or into the cultch layer. Within the crown area, the cultch layer was several inches thick and it was difficult to insert the cane pole into or through the layer. Using this method, the crown area at each test-plot was successfully relocated on several occasions over a 20-month period between October 2000 and June 2002.

The average planting time per test-plot was less than thirty (30) minutes. The average distances between the planted sites were approximately 165 feet from north to south, with a range of between 103 and 248 feet, and 196 feet from east to west, with a range of between 127 and 244 feet (see Figure 4-3). The remaining, small amounts (less than 10 to 15 cubic yards) of the test-plot cultch materials that could not be efficiently planted with the clam bucket were planted with the PMC water-spray guns (that were also mounted on the crane barge) in the northwest corner of the Half-Moon Island Plant Site in the area of the May 2000 cultch planting.

The cane pole markers at each test-plot site were replaced with a 20-ft section of 2-inch-diameter PVC pipe and the GPS coordinates of the PVC markers were recorded with the LDWF's Furuno Navigator GPS (without differential correction). Digital, 35-mm pictures and an 8-mm video taping of the test-plot plantings were taken by Ed Cake of CCS from aboard either the LDWF vessel or the PMC crane barge and tug. The pictures and video were previously submitted to LDWF officials with the November 2000 report entitled, "Preliminary Summary Report of the Fall (October 2000) Shell-Planting Activities at the Half-Moon Island Plant Site."

Test-Plot Sampling

On 12 July 2001, nine (9) months after the test-plots were planted, the site was visited to re-locate and re-mark, if necessary, the test-plots and to examine their condition in preparation for performance-assessment sampling. Scheduled attempts to visit the site earlier were hampered by either inclement weather or conflicting schedules. John Cirino of CCS was accompanied and assisted by Mark Lawson of the LDWF's Slidell office aboard their 25-foot, Boston Whaler vessel. Only two (2) of the nine (9) PVC pipes used to mark the test-plots were located and both displayed damage possibly caused by vessel and/or propeller impacts. Using a cane pole, the recorded GPS coordinates for the test-plots, and the GPS unit onboard the LDWF vessel, all nine (9) test-plots and their crown areas were located and re-marked with flagged, cane poles in preparation for sampling during the following days. Poling indicated that the central crown area at each test-plot was still evident and had not been buried by sediments.

Two (2) of the test-plots were examined using the LDWF's oyster hand-dredge. Several samplings with the hand-dredge at both sites failed to produce any significant numbers of oysters and/or cultch material. Only one piece of concrete cultch was retrieved and it was wedged between the dredge teeth. That piece of cultch was encrusted with a few, very small barnacles and one (1) small (<10 mm) oyster spat. These results indicated that the test-plots did not successfully "catch" a set of oysters in the nine (9) months since the planting of 3 October 2000. The presence of the very small barnacles and oyster spat indicated that a set was just beginning to occur.

These indications were supported by sampling conducted earlier in the week by Mark Lawson of the 3 October 2000 cultch plantings within the Half-Moon Island Plant Site just north of the test-plot sites. Lawson sampled this area with the same hand-dredge and collected four (4), 1.0-meter-square quadrate samples with SCUBA gear. Dredge sampling failed to produce any oysters and/or cultch material and quadrate sampling indicated exposed cultch on the bottom that was encrusted with only small barnacles and a few, small oyster spat.

Had a successful set occurred, the oysters should have been of sufficient sizes to be retained within the dredge bag. The cultch material alone was too small and readily passed through the dredge bag. For comparison, dredge samplings with the same hand-dredge conducted in the northwest-corner area of the May 2000 cultch planting, yielded numerous clusters of oysters set on all three (3) types of the same cultch materials used for the test-plots. The mean size of those oysters was 39.2 millimeters (1.5 inches) just four (4) months after planting.

Considering the lack of oysters on which to base the performance assessment, CCS recommended to the LDWF that the assessment be postponed until the test-plots caught a successful set of oysters. LDWF agreed with the recommendation and the contract between

CCS and LDWF was extended from 31 August 2001 until 30 June 2002 to allow sufficient time for an oyster set to occur and for subsequent growth of that set to seed size.

The failed oyster set at the test-plot sites and the October 2000 cultch planting area may have been caused by the late planting date. A hand-dredge sample collected on 2 October 2000 from the northwest-corner area of the May 2000 planting indicated that a successful oyster set occurred within the four (4) months between May and October 2000. The mean size of the spat oysters (0 to 25 mm) within that sample was 17.5 millimeters and the majority (64%) of the spat oysters were at or above the mean size, which suggests that the spat present were several weeks old and that new spat-set was diminishing. The overall mean size of the oysters sampled was approximately 39.2 millimeters (1.5 inches) with a range of 3 to 66 millimeters (<1 inch to 2.6 inches).

The oyster-set failure may also have been the result of unfavorable salinities following the October 2000 planting; however, a hand-dredge sample collected on 12 July 2001 from the northwest-corner area of the May 2000 planting, included a distinct group of oysters between 1 to 40 millimeters (<1 inch to 1.6 inches) with a mean size of 24 millimeters. Those data suggest that oysters successfully set within the May 2000 plant area between October 2000 and July 2001 and poses questions as to why no oysters successfully set at the test-plot sites or the October 2000 plant area during the same period.

Perhaps, the resulting larger oysters that grew following the successful May 2000 oyster set offered some advantage to the oysters setting between October 2000 and July 2001. Predation and/or the slower, winter growth-rate of oysters may have also been factors. Additional investigations should be made in an attempt to address the apparent paradox and should examine salinity records for the area, population dynamics data from similar oyster reef areas and/or cultch planting activities in the vicinity, and related literature.

Following the 12 July 2001 test-plot site visit, the site was re-visited on 18 October 2001 to check on the progress of the spat-set that was just beginning to appear at the time of the 12 July 2001 inspection. John Cirino of CCS was accompanied and assisted by Mark Lawson of the LDWF's Slidell office aboard their 25-foot, Boston Whaler vessel. Patrick Banks and Jack Isaacs of LDWF's Baton Rouge office also participated in the site visit.

One of the test-plot sites was located and sampled with CCS's hand-dredge. A 1-inch-stretch, plastic, Vexar mesh liner was inserted in the bag of the dredge to facilitate the collection of small oysters and/or cultch pieces. The Middle Concrete test-plot site (see Figure 4-3) was sampled. Sampling results indicated numerous young oysters set on the concrete cultch. The mean size of the oysters was 24.9 millimeters (1 inch = 25.4 mm) with a range of 12 to 44 millimeters (0.5 inch to 1.7 inches) after three (3) months of apparent growth since 12 July 2001.

The resulting oyster-size data from the 18 October 2001 test-plot sample were similar to the data obtained for the oysters sampled on 2 October 2000 from the northwest-corner area of the May 2000 planting four (4) months after planting. Both samplings occurred in October after 3 and 4 months, respectively, following an oyster set. The mean size of the oysters from the October 2000 sampling was 39.2 millimeters (1.5 inches) with a range of 3 to 66 millimeters (<1 inch to 2.6 inches); however, the majority of the oysters were between 12 to 56 millimeters. Notably, both samples contained no or relatively few spat oysters (0 to 25 mm) less than 12 millimeters which suggests that the spat were several weeks old and that new spat set was diminishing. It further supports that October may be too late a date to obtain a successful oyster set on cultch plantings.

Sampling of the test-plot sites for performance assessment was tentatively scheduled for sometime between February and April 2002. This was the period selected (6 to 9 months) in the assessment design between cultch planting and performance sampling to allow sufficient time for the oysters to set on the cultch and grow to seed size of 1 to 3 inches (25 to 76 millimeters). Several sampling efforts were canceled because of inclement weather or conflicting schedules between CCS and LDWF. Due to the sampling delays caused by scheduling conflicts and inclement weather, an additional contract extension was requested and a 30-day extension was granted from 30 June 2002 to 31 July 2002. Samples were collected on 7, 12, and 28 June 2002, which was approximately 11 months after an oyster set began and 9 months after the oyster set was confirmed.

On 7 June 2002, the crown areas of all nine (9) test-plots were successfully relocated and marked with the methods previously described above. The three (3) test-plots in the northern row of the site (Northwest Concrete, North Middle Limestone, and Northeast Oyster Shells) (see Figure 4-3) were collected in the manner previously described above. Bottom water salinity at the site was 16.0 parts per thousand, bottom water temperature was 28.5 degrees Celsius, and water depths ranged from 13.5 to 14 feet. Read Hendon of CCS collected the quadrate samples and was assisted by John Cirino of CCS. Tommy Rowley of the LDWF's Slidell office and Patrick Banks of the Baton Rouge office assisted with the sampling effort which was conducted from the LDWF's 25-foot, Boston Whaler vessel.

On 12 June 2002, the remaining six (6) test-plots were sampled using the same manner and methods described above. Bottom water salinity at the site was 16.0 parts per thousand, bottom water temperature was 28.0 degrees Celsius, and water depths ranged from 13.5 to 14 feet. Quadrate samples were collected by Read Hendon and John Cirino of CCS with the assistance of Tommy Rowley of the LDWF's Slidell office. The average time to collect the three (3), 0.33-square-meter quadrates samples at each test-plot was approximately forty (40) minutes. In all, twenty-seven (27), 0.33-meter-square quadrate samples were collected from the nine (9) test-plot sites. A total of nine (9), individual, quadrate samples for each of the three (3) different cultch types (crushed concrete, crushed limestone, and crushed oyster shells) were collected.

Analyses of the sample collected from the West-Middle-Oyster-Shells test-plot on 12 June 2002 indicated that the sample was atypical in comparison to the other test-plot samples previously analyzed. The sample was "contaminated" with extraneous materials including crushed concrete, *Rangia* clam shells, and whole and broken oyster shells. Atypically-larger oysters were attached to the clam and oyster shells. That information suggested that the original sample had been collected off-site of the test-plot in an existing reef area of oysters and shells and near the outer edge of one of the concrete sites, most likely, the Northwest site.

A review of the poling data transects of bottom consistency for the Half-Moon Island Survey Area that were contained in the report cited in the Introduction section herein and entitled, "Investigation and Identification of Selected Areas in Lake Borgne, Louisiana, Suitable for Oyster Cultch Planting," revealed that there were existing shells in the vicinity of the West Middle test-plot site (refer to Figure 5-2 on page 21 of that report and see Figures 4-2 & 4-3 herein). Also, a review of the GPS coordinates for the test-plot suggested that the sample was collected farther to the east and north of the actual test-plot site, which would have been in the area of the existing shells and the perimeter of the Northwest Concrete site. On 28 June 2002, the West-Middle-Oyster-Shells test-plot was accurately re-sampled by John Cirino and Read Hendon of CCS with assistance from Tommy Rowley of the LDWF.

Data and Statistical Analyses

The test-plot samples were analyzed using the methods described above in the Materials & Methods section. Oysters in the samples were identified and measured between 9 and 11 June, 18 and 23 June and on 30 June 2002. Data from the "contaminated" West-Middle-Oyster-Shells sample was replaced with the data from the sample collected on 28 June 2002. Performance assessment of the various cultch types was based on the production of seed oysters; therefore, only the live oyster data were used. Data on mortality figures were not analyzed for this report due to time constraints and because performance was based on live oyster production. A cursory examination of those data during and after sample analyses suggests that mortalities were similar; however, the data are available for analyses at a later date, if desired. Likewise, information on the abundance and size of fouling organisms and other general remarks regarding the test-plot samples were not analyzed, but also, appeared similar.

Between 11 and 17 July 2002, the live oysters measured were tallied in 3-mm size groups to determine the mean size and total number of live oysters for each sample. Live oysters less than 15 millimeters were not tallied. These numbers were omitted to exclude the group of young oyster spat that were just beginning to set within the test-plot area at the time of sampling (June 2002). Since the test-plots were not all sampled on the same date, it was possible that a significant number of young spat could have set on the plots sampled at the later dates and thereby, skewed the performance results. Also, as the mortality rates for spat are high and performance was based on seed oyster production, it was felt that it would be inappropriate to count these smaller oysters as seed production.

CCS also considered excluding all live oysters below the seed-size lower limit of 25 millimeters (1 inch); however, it was felt that a 15- to 25-mm oyster had survived for a sufficient period of time to be considered as part of the potential seed production. An examination of the size frequency graphs in Appendices A and B suggests that either exclusionary limit was appropriate as the numbers of oysters between the 15- to 25-mm range were fairly even and the majority of the oysters were above the 25-mm range.

Also, a few, atypically-large oysters were also omitted from the final tally numbers used for statistical analyses. A total of only four (4) oysters, that occurred in three (3) of the twenty-seven (27) quadrate samples, were omitted and they ranged in size from 90 to 104 millimeters. Their numbers were included in calculations of the original tally figures and did not significantly affect total numbers, nor appear to significantly affect mean size; however, they were omitted because their size was well outside the group range (see Appendix A).

Those larger oysters may represent a few individuals that set following the October 2000 planting and managed to survive whatever conditions or factors prevented a larger number of other oysters from setting and/or surviving. They may also represent genetically faster-growing oysters. Also, they may have simply fallen off a passing oyster boat or already have been present and somehow managed to end up on top of the test-plot sites. While their presence didn't affect the results, it raises interesting questions about their origin which may be answerable with additional investigation.

The mean sizes in millimeters (mm) of the oysters for the different cultch types from the samples collected in June 2002 (8 months after the 18 October 2001 site inspection) were 34.3 mm for concrete, 30.5 mm for limestone, and 34.6 mm for oyster shells and the standard error (or range) was small (see Table 4-1). In comparison, the mean size of the oysters in the sample from the Middle Concrete test-plot collected on 18. October 2001 was 24.9 mm. The increase in mean size of the oysters on the test-plots during the 8-month period between October 2001 and June 2002 was approximately between 5 to 10 mm.

Based on the size groups of oysters observed over time in samples from the northwest-corner area of the May 2000 cultch planting, it was anticipated that the mean size and range of the oysters at the test-plots would have been higher when sampled after an additional 8 months of growth. The small increase may have been due to slower growth rates during the winter months. Another possibility is that significant mortalities caused by unfavorable salinity or other factors may have occurred following the October 2001 sampling and the oysters sampled in June 2002 were recently set during the preceding months. This possibility was also suggested

Table 4- 1. Descriptive Statistics for Oyster Abundance and Size Data

	CONCRETE	LIMESTONE	OYSTER SHELL
No. of Observations	9	9	9
No. Live Oysters	143.2 ± 18.42	103.6 ± 18.89	28.8 ± 4.17
Size (mm)	34.3 ± 0.44	30.5 ± 0.43	34.6 ± 0.63
Rank Abundance	20.67	16.22	5.11
Rank Size (mm)	17.61	5.44	18.94

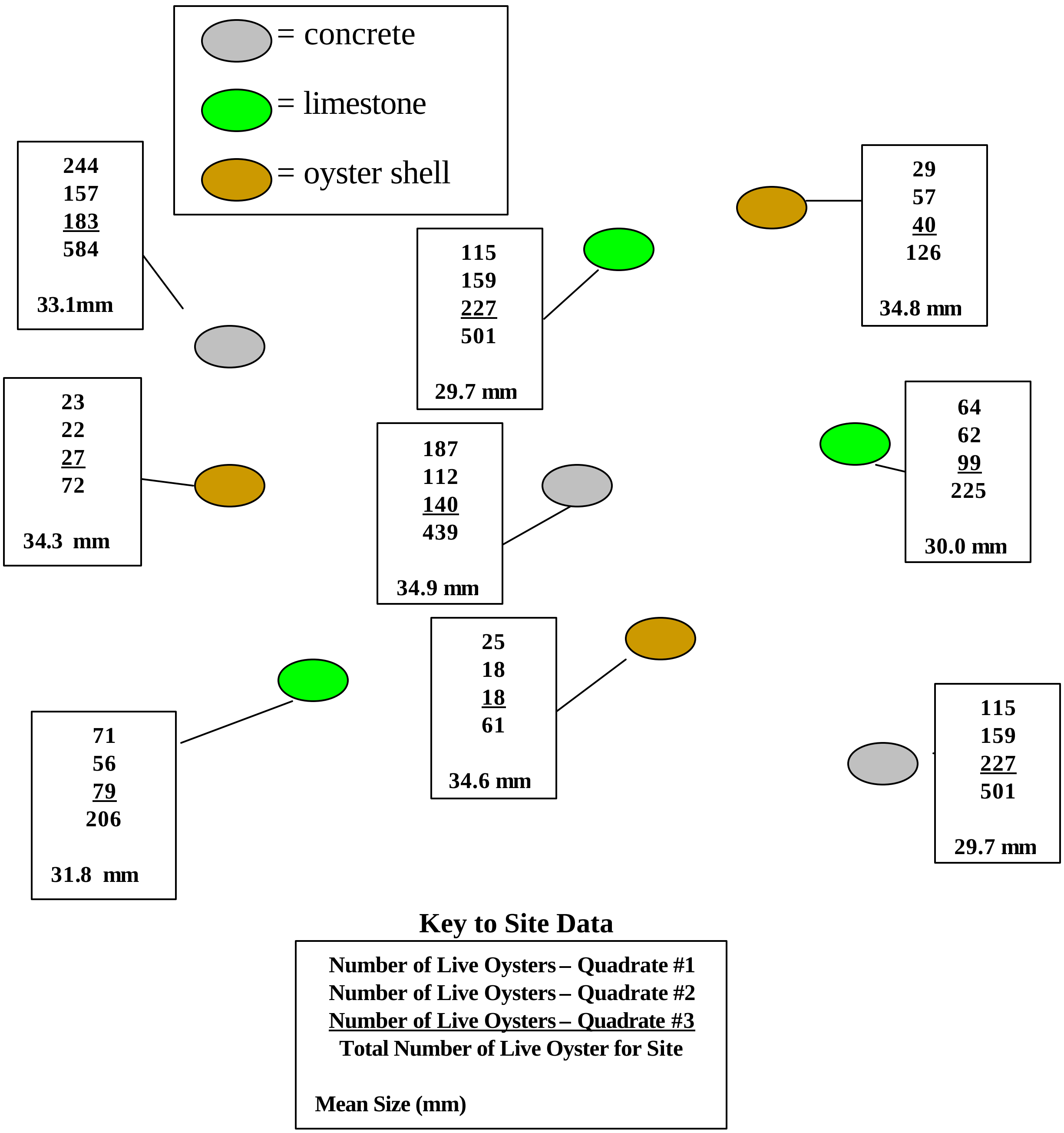
by the large numbers of old, dead, oyster valves and boxes in the samples. The approximate mean size of those dead oysters was similar to the mean size of the oysters in the October 2001 sample (25.8 mm vs 24.9 mm). As discussed above, with regards to the failed October 2000 oyster set, a review of salinity records for the area, population dynamics data from similar oyster reef areas and/or cultch planting activities in the vicinity, and related literature may provide additional insight into issue.

Data on the numbers of live oysters and their mean sizes (see Figure 4-4) were statistically analyzed by Read Hendon of CCS as described in the Materials and Methods section above. Descriptive statistics and mean ranks, as determined by the Kruskal-Wallis test, for oyster abundance and size for the three (3) cultch types are presented in Table 4-1. Mean ranks for pair-wise comparisons of the data using the Mann-Whitney U-test are provided in Table 4-2.

Table 4-2. Mean Ranks for Pair-wise Comparisons of Oyster Abundance and Mean Size among Cultch Types

No. of Live Oysters			
Comparison	Rank	Rank	P-value
Concrete vs. Limestone	Concrete = 11.67	Limestone = 7.33	0.094
Concrete vs. Oyster Shell	Concrete = 14.00	Oyster Shell = 5.00	< 0.001
Limestone vs. Oyster Shell	Limestone = 13.89	Oyster Shell = 5.11	< 0.001
Mean Oyster Size (mm)			
Comparison	Rank	Rank	P-value
Concrete vs. Limestone	Concrete = 13.89	Limestone = 5.11	< 0.001
Concrete vs. Oyster Shell	Concrete = 8.72	Oyster Shell = 10.28	0.546
Limestone vs. Oyster Shell	Limestone = 5.33	Oyster Shell = 13.67	< 0.001

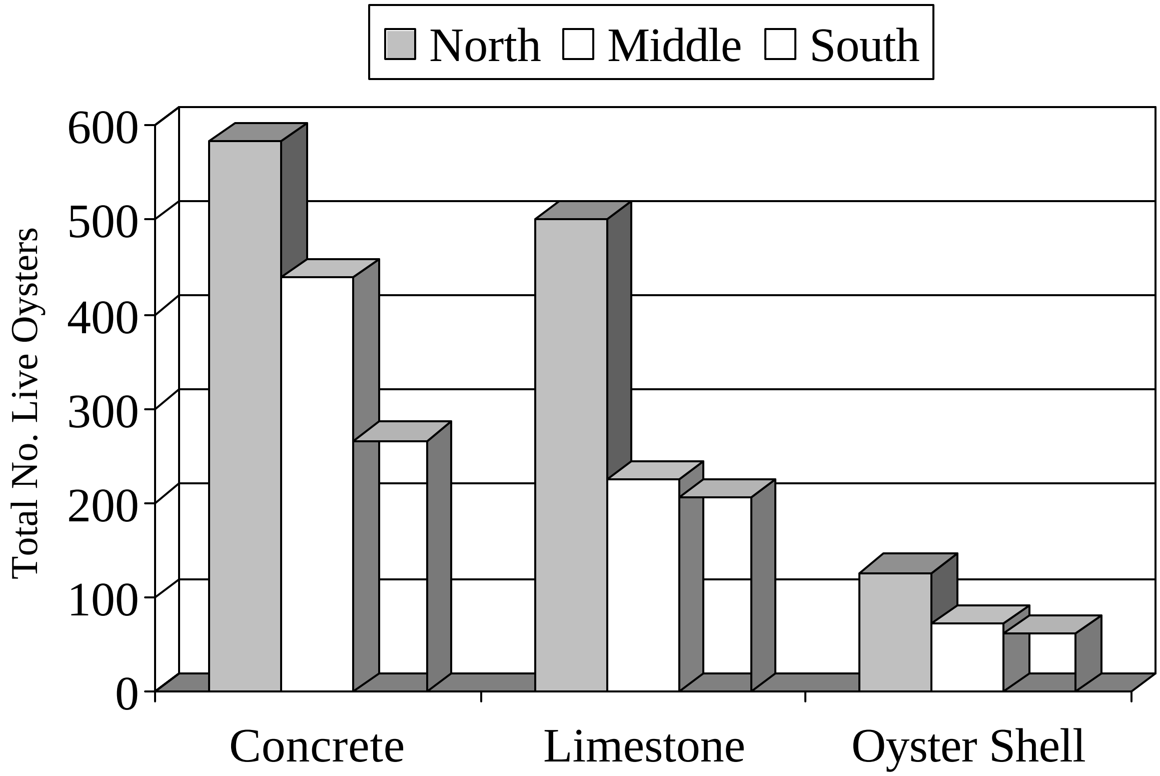
Figure 4-4. Number and Mean Size (mm) of Live Oysters per Test-Plot Site



The Kruskal-Wallis test detected a significant difference in both abundance ($?^2$ = 18.35; df = 2; p < 0.001) and mean size ($?^2$ = 15.82; df = 2; p < 0.001) among the three (3) cultch types. Pairwise comparisons of abundance data (see Figure 4-5) revealed that the numbers of live oysters associated with both concrete and limestone were significantly higher that those associated with the oyster shells (p < 0.001 for each). Abundance did not differ between the concrete and limestone (p = 0.094). The mean size of the oysters sampled (see Table 4-1 and Appendix A) was significantly higher at both the concrete and oyster shells in relation to the limestone (p < 0.001 for each), but no difference in mean size was detected between the concrete and oyster shells (p = 0.546).

To determine whether or not spatial positioning of the test-plots significantly influenced oyster abundance or mean size, statistical comparisons using the Kruskal-Wallis test were made among the three (3) test-plots of each cultch type. Mean oyster size did not differ among the concrete sites ($?^2$ = 3.289; df = 2; p = 0.193), limestone sites ($?^2$ = 4.356; df = 2; p = 0.113), or oyster shells sites ($?^2$ = 0.157; df = 2; p = 0.925), suggesting that spatial placement of the cultch did not influence differences observed in mean size. For oyster abundance, no significance levels less than the threshold of 0.05 were detected, although comparisons of abundance among the three (3) sites of concrete ($?^2$ =6.006; df = 2; p= 0.050, limestone ($?^2$ = 5.422; df =2; p = 0.066), and oyster shells ($?^2$ = 6.006; df = 2; p = 0.050) each yielded p-values very near this level. For each of the cultch types, mean rank abundance was highest at the northernmost site and lowest at the southernmost site.

Figure 5. Total Number of Live Oysters Per Cultch Type and Latitudinal Location of Test-Plot Site.



Based on the general ratio of oysters caught by cultch type along each of the latitudinal rows (see Figure 4-3), latitudinal variation did not vary greatly. The ratio of concrete, limestone, and oyster shells was as follows:

Concrete : Limestone : Oyster Shells

North	=	5 : 4 : 1 (48 : 41 : 10)
Middle	=	6 : 3 : 1 (59 : 31 : 10)
South	=	5 : 4 : 1 (46 : 42 : 12)

Summary Results

Based on the production of seed oysters in terms of numbers and mean size per cultch type, the crushed concrete #57 proved to be the best cultch performer. Results from a similar study conducted between August 1994 and June 1996 in Hackberry Bay, Louisiana, also indicated that crushed concrete was the better performer in terms of mean oyster abundance for the first year of seed production, though there was no significant difference between the crushed concrete and shucked (oyster) shells. During the second year of study, shucked shells replaced crushed concrete in terms of mean abundance; however, the crushed concrete had the highest combined mean for the 2-year period. As the test-plot sites were just beginning to receive another good spat set when sampled in June 2002, it would be interesting and may prove useful to examine the numbers and mean-size groups of oysters per cultch type following a second year of oyster set and growth.

That study was entitled, "Evaluation of Six Oyster Cultch Materials in Hackberry Bay, LA," and was conducted by the Louisiana Department of Wildlife and Fisheries. The cultch materials used in that study were crushed concrete, shucked shells, reef shells, mixed shells, Kentucky limestone, and Bahamian limestone. It is unknown if the sizes of the crushed concrete and limestone used were similar to the size #57 used herein. Additional studies comparing different types of cultch materials have been conducted; however, time constraints prevented a comparison of their methods and results with those herein. A thorough review of existing, related literature may provide additional insight regarding cultch material performance and the results noted herein.

In summary, the following results were supported or suggested by this study:

1. In terms of the number of live oysters present, crushed concrete #57 and crushed limestone #57 were statistically better-performing cultch materials than crushed oyster shells.

2. Based on overall abundance data, crushed concrete #57 appears to be the best-performing cultch type in terms of numbers of live oysters caught.

3. Taking #1 and #2 above into account, the study showed crushed concrete #57 to be the best cultch type for seed production because:

   (a) Crushed limestone #57 caught fewer oysters on average (although not significantly different) than crushed concrete #57 and had the statistically lowest mean size.

   (b) Crushed oyster shells may have had about the same size oysters as did the crushed concrete #57, but the numbers of oysters caught were the lowest statistically.

   (c) Crushed concrete #57, on average, caught the most oysters and mean size was just as high as that of the crushed oyster shells.

4. Mean size did not differ statistically from the northern test-plot sites to the southern sites within a cultch type.

5. Although not statistically different, the numbers of live oysters present were highest at the northernmost sites and lowest at the southernmost sites for each of the cultch types.

6. Based on the volume lost and the poor performance, crushing the oyster shells to a size that approximates #57 crushed concrete and limestone was detrimental.

7. The best use of oyster shells may be as whole shells based on their similar performance to crushed concrete and their increased surface-area volume noted in the Hackberry Bay study.

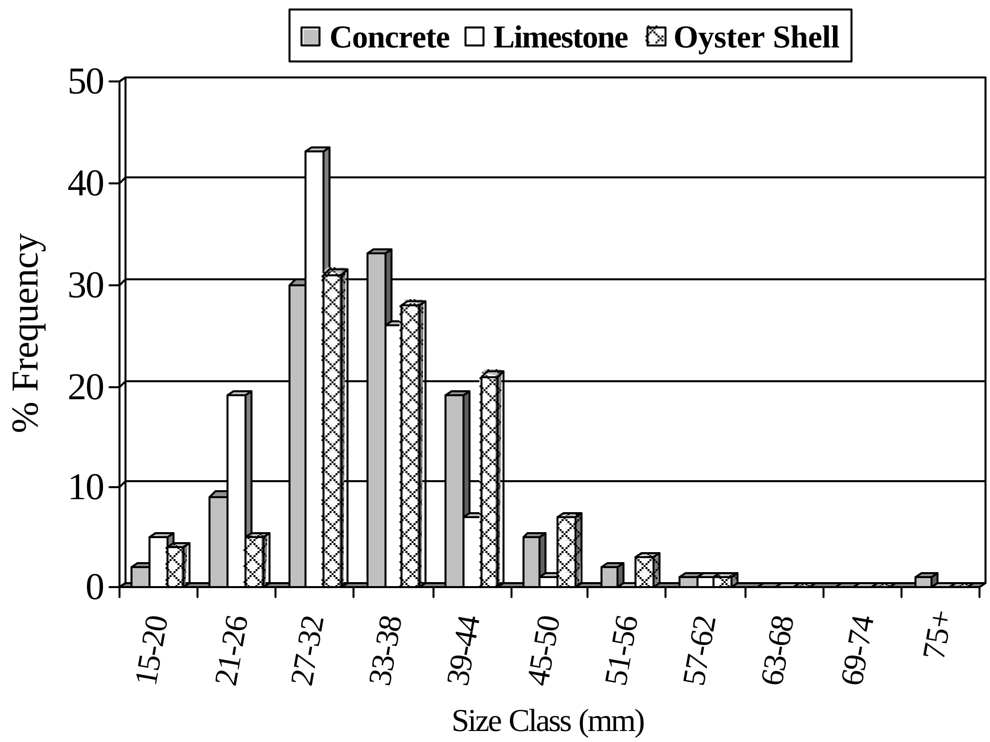
8. October may be too late a date for cultch planting activities is a successful set is desired in the same year.

9. Another assessment of cultch-type performance at the test-plot sites using the methods herein should be conducted within 6 to 12 months following the oyster set that was beginning to occur in June 2002.

Appendix A

Percent Size Frequency (mm) of Live Oysters Per Cultch Type

Appendix A. Percent Size Frequency (mm) of Live Oysters Per Cultch Type



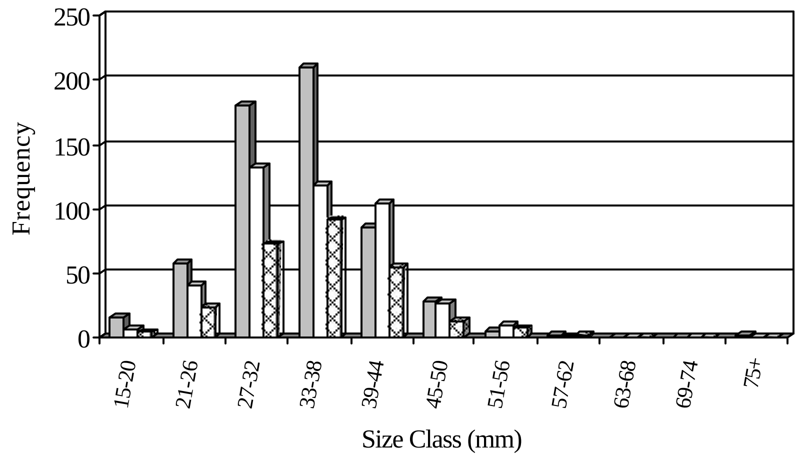
Appendix B

Size Frequency of Live Oysters (mm) Per Cultch Type
and Latitudinal Placement of Test-Plots

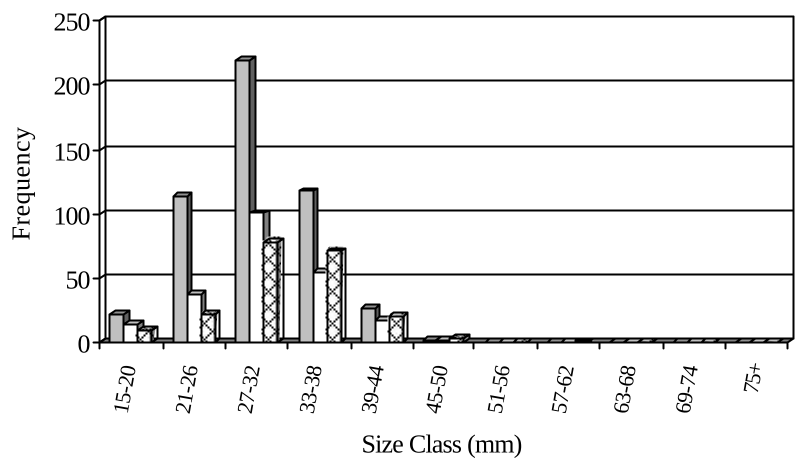
Appendix B. Size Frequency (mm) of Live Oysters Per Cultch Type and Latitudinal Placement of Test-Plots.

(Note that y-axis scale differs for OYSTER SHELL data.)

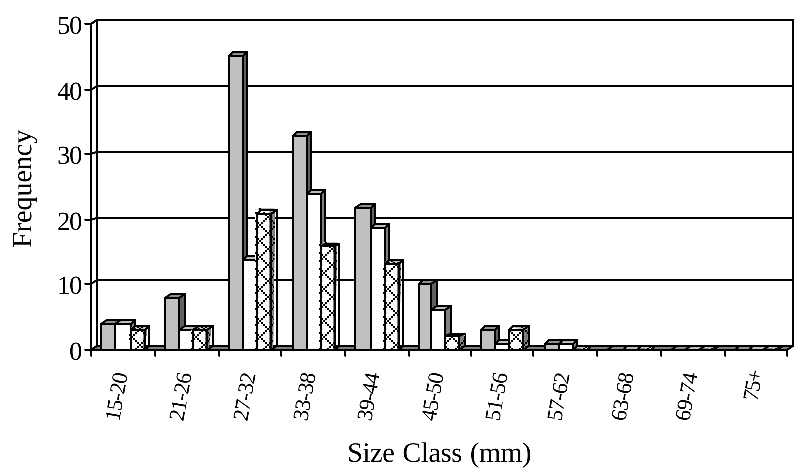
NORTH MIDDLE SOUTH



CONCRETE



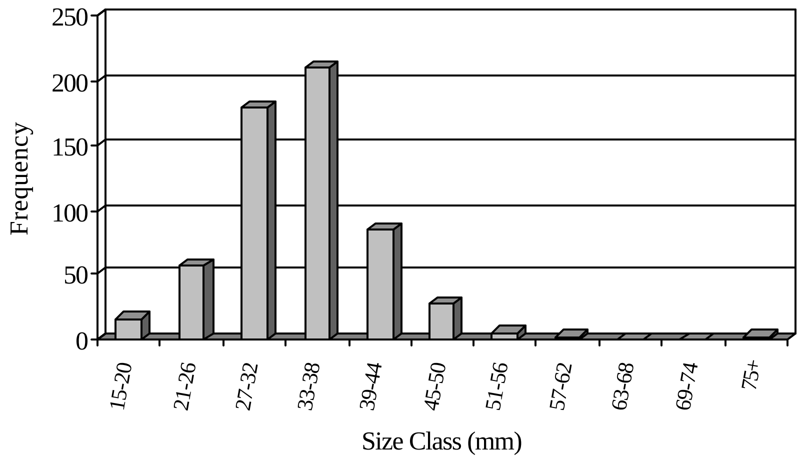
LIMESTONE



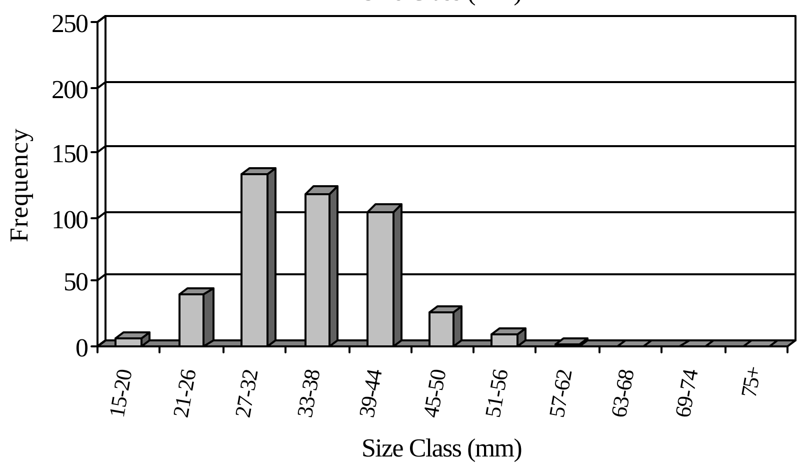
OYSTER SHELL

Appendix B. Size Frequency (mm) of Live Oysters By Latitudinal Placement of Test-Plot: CONCRETE.

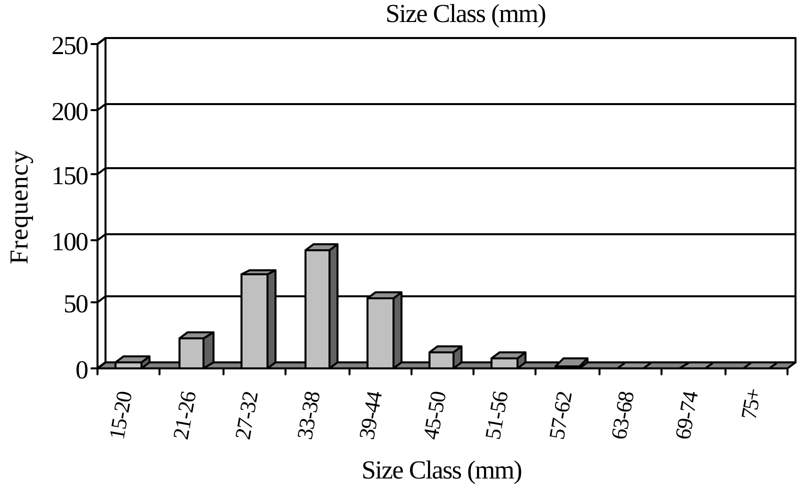
CONCRETE SUBSTRATE



NORTH

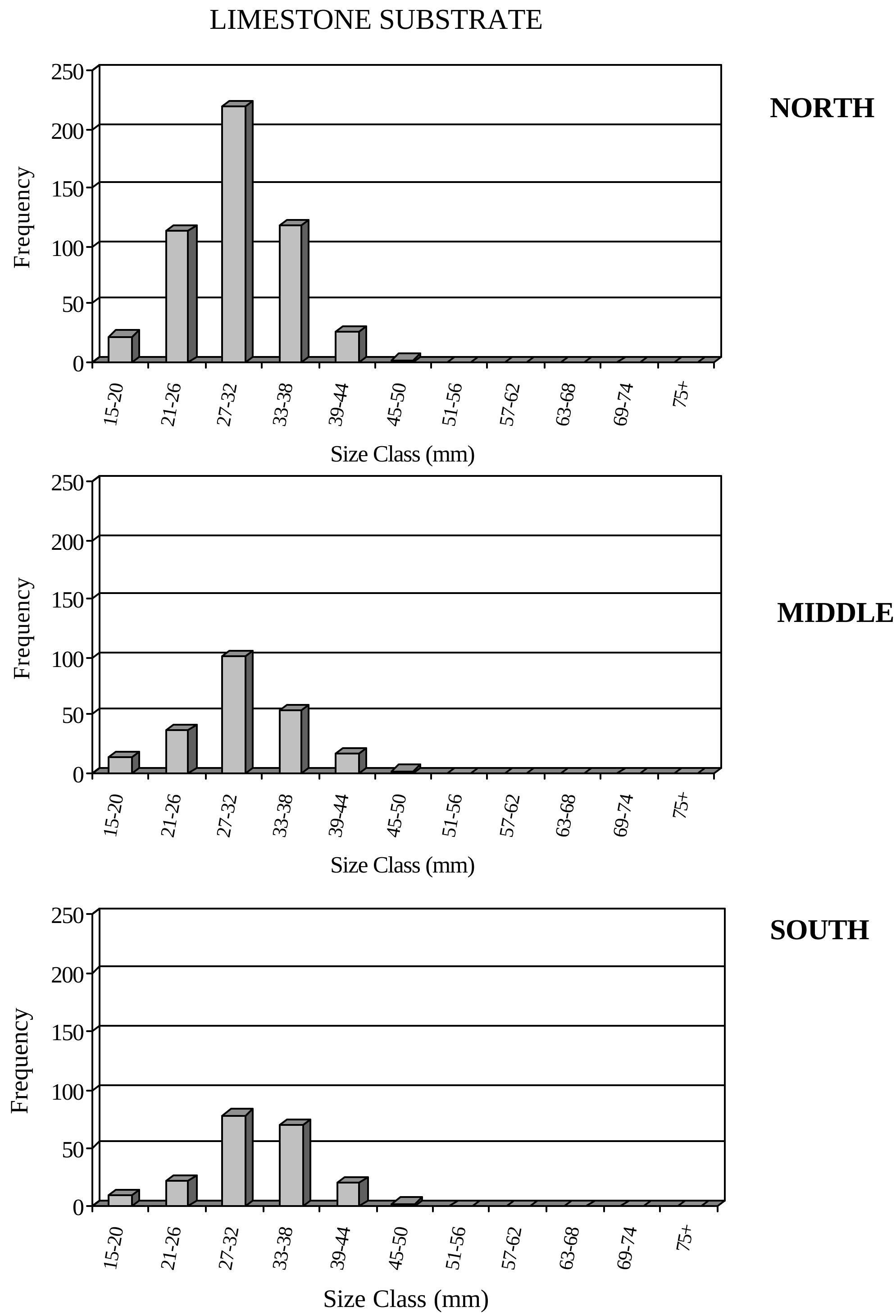


MIDDLE

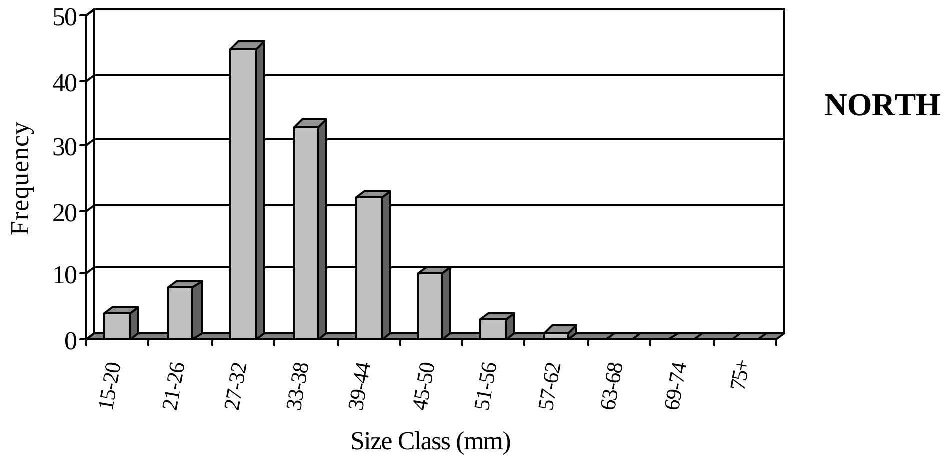


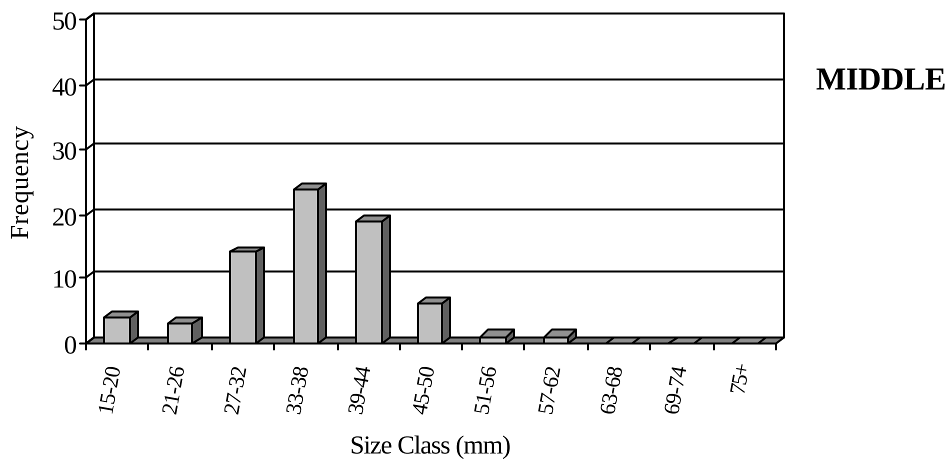
SOUTH

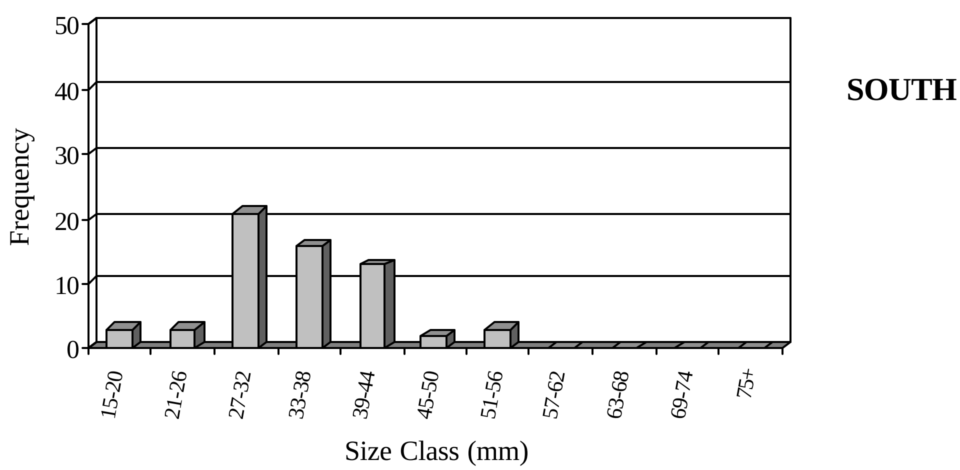
Appendix B. Size Frequency (mm) of Live Oysters By Latitudinal Placement of Test-Plot: LIMESTONE.



Appendix B. Size Frequency (mm) of Live Oysters By Latitudinal Placement of Test-Plot: OYSTER SHELL.







Appendix C

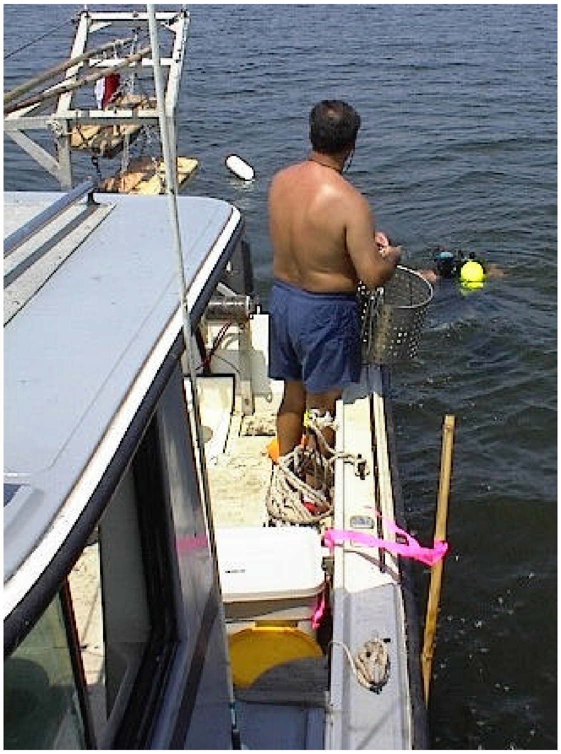
Pictures of Test-Plot Planting & Sampling


Crushed Concrete


Crushed Limestone


Crushed Oyster Shells

Bucket Placement



Quadrate Sampling

Quadrate Sample: Concrete

Quadrate Sample: Limestone

Quadrate Sample: Oyster Shells

Appendix D.

Presentations Made in Conjunction with the
Louisiana Oyster Shell Recovery Pilot Project
Funded by the National Marine Fisheries Service
Grant Number NA96FK0188

Presentations Made in Conjunction with the
Louisiana Oyster Shell Recovery Pilot Project
Funded by the National Marine Fisheries Service
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Isaacs, Jack C., Walter R. Keithly, Jr., and Assane Diagne. "Use and Value of Oyster Reefs among Recreational Fishermen in Louisiana." Paper Presented at the Annual Meeting of the National Shellfish Association, Mystic, Connecticut, April 14 – 18, 2002.

Isaacs, Jack C., Walter R. Keithly, Jr., and Assane Diagne. "Consumer Surplus of Recreational Anglers over Louisiana Oyster Reefs." Poster Presented at the American Water Resources Association, 2002 Spring Specialty Conference on Coastal Water Resources, New Orleans, Louisiana, May 13 – 15, 2002.

Isaacs, Jack C., Walter R. Keithly, Jr., and Assane Diagne. "The Economic Value of Oyster Reefs to Louisiana Recreational Fishermen." Paper Presented at the International Conference on Shellfish Restoration, Charleston, South Carolina, November 20 – 24, 2002.

Isaacs, Jack C., Walter R. Keithly, Jr., and Assane Diagne. "The Economic Value of Oyster Reefs to Louisiana Recreational Fishermen" Paper Presented at the North American Association of Fisheries Economists 2003 Forum. Williamsburg, Virginia, May 4 - 7, 2003.